Some Objections to Project Application No. 10_0001 for the Cobbora Coal Mine

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Attachment 1: '*NSW's Great Big Coal Subsidy Scandal'*, Giles Parkinson, Climate Spectator November 1 2011: http://www.climatespectator.com.au/commentary/nsws-great-big-coal-subsidy-scandal

Attachment 2: '*Health and Social Harms of Coal Mining in Local Communities - Spotlight on the Hunter Regio*n', Ruth Colagiuri, Johanne Cochrane and Seham Girgis, Health and Sustainability Unit, The Boden Institute for Obesity, Nutrition and Exercise, The University of Sydney, October 2012.

Attachment 3: '*The End of Camberwell'*, Rivers-SOS Media Release October 16 2012.

Attachment 4: '*Full cost accounting for the life cycle of coal'*, Paul R. Epstein, Jonathan J. Buonocore, Kevin Eckerle, Michael Hendryx, Benjamin M. Stout III, Richard Heinberg, Richard W. Clapp, Beverly May, Nancy L. Reinhart, Melissa M. Ahern, Samir K. Doshi, and Leslie Glustrom, *Ann. N.Y. Acad. Sci*. 1219 (2011) 73–98.

Attachment 5: '*The Social Cost of Coal: Implications for the World Bank'*, Samuel Grausz October 2011, Climate Advisors.

Attachment 6: '*Some Comments on the Draft NSW Renewable Energy Action Plan',* Northern Illawarra Sustainability Alliance, November 2012.

Attachment 7: '*Taking Our Temperature'*, ABC Catalyst November 15 2012: http://www.abc.net.au/catalyst/stories/3633447.htm

Attachment 8: '*World Energy Outlook 2012 - Executive Summary'*, International energy Agency, November 2012. http://www.iea.org/publications/freepublications/publication/name,33339,en.html

Objections to Proposal 10_0001 for the Cobbora Coal Mine

General Comments

Limited available time to review the proposal during the exhibition period restricts this submission to a set of attachments addressing relevant issues that highlight the tragic and scandalous folly of the Government's determination to pursue coal as an energy source irrespective of its health, social, environmental, climate and financial costs to the people of NSW.

The first attachment is an article in the Climate Spectator highlighting the scandalous tax-payer subsidisation of the Cobbora coal mine, which is clearly not in the public interest:
http://www.climatespectator.com.au/commentary/nsws-great-big-coal-subsidy-scandal

The second attachment is a recent University of Sydney report on the health and social impacts of coal mining, with a focus on the Hunter Valley:
http://beyondzeroemissions.org/blog/coal-health-report-121023

The third attachment is a media release from Rivers-SOS in response to the shameful 'about-face' approval of the Ashton Coal Mine by the PAC.

The fourth attachment is a publication in the Annals of the New York Academy of Sciences assessing the full life-cycle costs of coal.

The fifth attachment is also a report on the external costs of coal.

The sixth attachment is a submission to the draft NSW Renewable Energy Action Plan.

The seventh attachment is a transcript from the ABC Catalyst edition of November 15 2012, which presented a summary of climate change in Australia over the past 100 years. The video is available at the Web site: http://www.abc.net.au/catalyst/stories/3633447.htm

The eight attachments is the 2012 World Energy Outlook report from the IEA. Observations in the report include: '*Despite the growth in low carbon sources of energy, fossil fuels remain dominant in the global energy mix, supported by subsidies that amounted to $523 billion in 2011, up almost 30% on 2010 and six times more than subsidies to renewables*.' And '*No more than one-third of proven reserves of fossil fuels can be consumed prior to 2050 if the world is to achieve the 2 °C goal, unless carbon capture and storage (CCS) technology is widely deployed*.' There is no realistic prospect of wide spread cost effective and safe deployment of CCS. Nonetheless the NSW Government seems determined to ensure that all of the State's coal reserves are mined, regardless of location and impact.

The executive summary for the IEA report is available here:
http://www.iea.org/publications/freepublications/publication/name,33339,en.html

Comments on the PAC

Coal mining kills and harms, and environmentally wrecks NSW. The NSW Planning Assessment Commission was established to address concerns of a lack of independence in the assessment of mining project proposals, with the State Government having a clear conflict of interest where proposed projects would deliver royalties. In practice the PAC has made little difference. While it has imposed tighter conditions of approval, it has nonetheless continued the succession of harmful project approvals that undermined the public's confidence in the NSW assessment and regulatory system. The PAC assessment of the Bulli Seam Operations (BSO) project was a notable exception, for which however the political circumstances were favourable. The BSO assessment stands in contrast, for instance, to the more recent disgraceful approval of the Ashton Coal Mine. The PAC has little credibility in the informed community.

Approval of the Cobbora coal mine will annually add for 21 years at least 36 million tonnes of carbon dioxide and an unknown amount of methane to the global greenhouse gas burden. Hardly something of which to be proud.

NSW's Great Big Coal Subsidy Scandal

Giles Parkinson, Climate Spectator, November 1 2011
http://www.climatespectator.com.au/commentary/nsws-great-big-coal-subsidy-scandal

If there is a single mechanism that stands in the way of clean energy development across the globe it is fossil fuel subsidies, which amount to around half a trillion dollar worldwide, each year. That much has been recognised by the International Energy Agency and by the G20, who have promised to remove them.

The IEA says that by doing that, more money can be freed up to invest in the technologies of the future. Given the course of the debate in the US and Australia, don't expect that to happen any time soon.

To understand why this is so, take a look at this exchange reported on Monday by *Climate Progress*. It noted that the five biggest oil companies in the world last week reported third quarter profits of $32 billion, taking total earnings for the year to date to a staggering $100 billion. Would that possibly be a signal that Big Oil no longer needs the massive subsidies that the US Congress is so keen to afford it?

"Of course not," shouted the Republicans. Florida Congressman Cliff Stearns is the chairman of a House sub-committee that has been investigating (and railing against) loan guarantees being offered to clean technologies. Stearns has voted multiple times to extend oil company subsidies but says clean energy incentives pick "winners and losers" (guess which Australian energy minister uses the same language in the same context). Stearns says it is much more fun just picking winners. "When somebody is successful, then you give them the subsidies and the tax credit," he told *Climate Progress*, when asked if the oil companies should maintain their subsidies.

That kind of logic is being repeated in Australia, where the Coalition and other established business figures have also been railing against clean energy incentives – it's like putting money on the horses, said Opposition finance minister Andrew Robb last week – and all the while extending support and protection for the status quo.

The Tamberlin inquiry into the NSW energy privatisation has revealed how far that thinking extended into the strategy behind the state's half-baked, and half-completed electricity privatisation. In short, it found, the gentrader assets would not have attracted any buyers were it not for a massively subsidised and heavily discounted coal supply. It also found that NSW coal-fired power stations depend on those subsidies to maintain their place in the merit order of the National Electricity Market.

We wrote about that subsidy when it first came to light late last year, when it was also lamented by the government's then climate change advisor Ross Garnaut, who said it acted against the carbon price. And the Tamberlin report released on Monday reveals that it is even worse than we first thought, and amounts to an effective subsidy of $4 billion to the gentraders that were sold by the government for just $1.5 billion. As the inquiry notes, with a degree of understatement, it's not entirely clear that the cost of the subsidy exceeds the benefit.

Of course, the NSW government doesn't want you to know this and has taken great steps to black out the key numbers in the report. But the numbats in the Premier's Department forgot that there's not much point blacking them out in one section of the report, if you leave them in elsewhere, or if they are included in other reports. So we've put the figures together for you.

One of the big issues around the gentrader sale was where they would source their future coal supplies. Contracts, mostly from Centennial Coal, were due to run out in coming years, and there was no way the would-be gentrader owners wanted to be exposed to buying coal at the current export price of thermal coal, which is around $100-$120/t. Or anywhere close to that.

So the government set up a tender for the Cobbora coal mine, a massive resource that could produce up to 30 million tonnes a year and may well supply all of the state's coal-fired power stations by 2020. Whitehaven Coal was the preferred tenderer, but even its offer of supplying coal at $55/t was deemed by Frontier Economics, an advisor to the NSW government, as "exorbitant". Frontier said, at this price, there would be no interest from the private sector in the gentrader contracts.

So the government decided to commit to spending $1.5 billion to develop the Cobbora mine itself (reversing a near 20 year-old policy), and supply coal to the generators at a vastly lower price. The Tamberlin inquiry blacks out the number, but includes a handy reference to the NSW auditor-general's report which says it was just $31.16 a tonne. Even at the state's estimated borrowing rate of 6 per cent (compared to the private sector's 15 per cent), it is not even enough to cover the cost of production, meaning that the state has got Buckley's chance of being able to sell it, despite Tamberlin's recommendation that it attempts to do so.

The state's advisors, including Arne Dimpfel from Credit Suisse, argued before Tamberlin that because both assets (the coal mine and the gentraders) were owned by the government, it was not in fact a subsidy. Better not try to run that argument past the IEA or the G20, who say government subsidies such as this are the most egregious; or, for that matter, the Tamberlin Inquiry's independent advisor Donald Challen, a former Treasury secretary in Tasmania and now chair of the transmission group, Transend.

Challen concluded that the subsidy was of considerable benefit to the gentraders because it reduces the volume and pricing risk. He noted that Ernst & Young had concluded that the mine's "unavoidable costs of meeting each coal supply agreement exceeded the revenues." He also noted that any owner, government or private, should receive a return on capital commensurate with the risks inherent in the investment. And this one clearly does not.

The magnitude of the shortfall of acceptable returns were also blacked out. But the revenue shortfall was not. Given that the contract is $24/t less than Whitehaven's offer, at around 10 million tonnes a year, and over 17 years, that's around $4 billion over the life of these contracts. This number is supported by Treasury calculations revealed elsewhere in the document.

Challen noted that the government still faces big risks with the Cobbora mine: these include its ability to get it up and running by 2015, when its first deliveries are due to start; that production will costs will rise; and that the mine, operating as a loss-making, state owned entity, will not be able to acquire the skills and expertise to efficiently operate at a large scale. And it may also be found that future coal prices will rise to such an extent that an even greater benefit is conferred on the gentraders.

Challen's assessment is damning: "The preliminary conclusion in considering the benefits and costs of the Cobbora development is therefore that a business case, had one existed, would have shown that the benefits of the development did not exceed the costs." The only justification, he said, was that without a massive subsidy, the gentrader sales would not have been completed as "potential buyers for the rights might well have regarded the fuel supply and price risk too high."

In short, this inquiry tells us, the coal-fired power stations in NSW are unable to compete with other power sources unless their coal is supplied at around one quarter of the cost of export coal. Given that Cobbora has the potential to supply 30 million tonnes of coal to the state's coal fired power plants by 2020, as noted by the Australian Energy Market Operator, the lost export revenue potential from the mine could amount to some $2.7 billion a year, at current prices.

The similarities between Australia (the world's largest coal exporter) and the Gulf oil states (the world's largest crude exporters), are uncanny. Neither can afford to consume their own fossil fuels at export prices. As we noted last week, the Gulf States are now looking to invest massively solar so they can reduce their domestic oil consumption and recoup the billion of dollars in lost revenue.

So here's a crazy idea. Maybe the NSW government should take the same approach, and invest heavily in solar, freeing up coal for export and having an established and ultimately lower cost solar industry to fall back on when the world finally gets really serious about cutting greenhouse emissions.

Imagine if NSW tries to sell the remaining coal-generation assets, as Tamberlin recommends. As the Australian Energy Market Operator states in its report, Cobbora will likely be supplying all of the state's coal-fired power plants by the end of the decade. We know from this report that the plants can't be sold at all without the subsidised cost of coal. But at its capacity of 30 million tonnes, at the current export price of $100-$120 a tonne, the state could generate $3-$3.6 billion *a year* in export revenue, compared to the $900 million it will receive from the state-owned coal generators at the current price.

That should be enough to build a few solar power stations, but we'd better make sure the NSW government understands that this is an idea from the Saudis, Kuwaitis, Omanis and the Emirates, and not some sort of subversive green plot. But you may want to ask them this: will the government's criteria on solar incentives, that it not cost a single dollar to either consumers or the government, now be applied to coal-fired generators?

2012

HEALTH AND SOCIAL HARMS OF COAL MINING IN LOCAL COMMUNITIES

Spotlight on the Hunter Region

HEALTH AND SOCIAL HARMS OF COAL MINING IN LOCAL COMMUNITIES:

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Commissioned by:
Beyond Zero Emissions (Australia)

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CONTENTS

PURPOSE OF THE REPORT

The purpose of this report is to provide an objective overview of the available international and local evidence from the health and medical literature about the health effects and social justice impacts of *coal mining on local communities* and to discuss and relate these issues to the Hunter Region of New South Wales

ACRONYMS

ACARP	Australian Coal Association Research Program
AHS	Area Health Service
BEACH	Bettering the Evaluation and Care of Health
BRFSS	Behavioural Risk Factor Surveillance System
CO_2	Carbon dioxide
COPD	Chronic obstructive pulmonary disease
CVD	Cardiovascular diseases
DNA	Deoxyribonucleic acid
DQ	Developmental Quotient
EDS	Environmental Distress Scale
GDP	Gross domestic product
GHG	Greenhouse gas
GIS	Geographic Information Systems
GP	General practitioner
HNEAHS	Hunter New England Area Health Service
HRQOL	Health Related Quality of Life
LGA	Local Government Area
LTLI	Long term limiting illness
MTM	Mountain top mining
N_2O	Nitrous oxide
NMSC	Non-melanoma skin cancer
NSW	New South Wales (Australia)
NTDs	Neural Tube Defects
PAHs	Polyaromatic hydrocarbons, polycyclic aromatic hydrocarbons
PAH –DNA	Polycyclic aromatic hydrocarbon-deoxyribonucleic acid
PFT	Pulmonary function test
$PM_{2.5}$	Particulate matter 2.5 micrometers or less in diameter
PM_{10}	Particulate matter 10 micrometers or less in diameter
QLD	Queensland (Australia)
SCI	Stream Condition Index
SIA	Social impact assessments
SO_2	Sulphur dioxide
TUNDRA	Tundra Degradation in the Russian Arctic
UK	United Kingdom
US	United States (of America)
VSL	Value of statistical life lost
8-OHdG	8-hydroxy-2-deoxyguanosine (a biomarker for oxidative stress)

Note:

1. Some studies cited in this Report used tonnes and others used tons as measures for quantifying amounts of coal extracted. It should be noted that these measures are not interchangeable and each term is used in the text according to which measure was reported by the authors of the research articles reviewed.

EXECUTIVE SUMMARY

Context

Australia is a major exporter of coal and relies heavily on coal powered electricity to meet the growing energy demands of its homes and offices, factories, retail outlets, and public facilities and services. Public concern about the environmental, community health, and social consequences associated with coal extraction and combustion has grown in tandem with the recent and rapid expansion of mining activity, and appears to be at an all time high.

These concerns are nowhere more apparent than in the Hunter Region of New South Wales (NSW) - Australia's oldest and most productive coal mining area - which has in excess of 30 mostly open-cut coal mines and six active coal-fired power stations. The Hunter Region includes 11 local government areas with a combined population of some 700,000 people whose livelihood is derived from a number of important industries including tourism, farming, grazing, wine growing and making, and race horse breeding, as well as coal mining. There have been multiple anecdotal reports of disease clusters associated with mining, and calls from various community organisations and local government for studies to explore and examine these issues.

Purpose, Scope and Methods

This independent Report was commissioned by Beyond Zero Emissions to examine and summarise what is known in the available research evidence from Australian and international health journals, and other relevant reports, about the health and social harms of mining activity for *people living in communities near coal mines and coal-fired power stations*, and to relate these issues to the Hunter Region of NSW.

After searching a variety of health databases and websites, a pragmatic review of the international peer reviewed health literature and selected reports from relevant government and non-government organisations was undertaken to identify background information and evidence that reflects what is known about the community health and social harms associated with coal mining activity and coal-fired power stations. Four central research questions were developed to guide the literature searches and provide a coherent reporting framework:

1. What specific diseases or other health problems are associated with coal mining in local communities?
2. Are there clusters of these diseases or other health problems in the Hunter Region of NSW?
3. Is social injustice associated with coal mining in local communities?
4. Is there an association between coal mining and social injustice in the Hunter Region of NSW?

Key Findings

There are clear indications from the international health research literature that there are serious health and social harms associated with coal mining and coal-fired power stations for people living in surrounding communities.

There are several studies about the social harms of coal mining from the Hunter Region but few Australian studies directly examine the health effects of coal mining or coal burning power stations on the health of local communities. Much of the peer reviewed literature comes from the Appalachian coal mining region of the United States (US). These studies, along with the majority of others we reviewed from the US, the United Kingdom (UK), Canada, Australia, Spain, Turkey, Israel, Eastern Europe and Asia indicate serious health impacts for communities living near coal mines and coal combusting power stations. In the absence of current local research evidence and despite possible differences in mining practices, it is reasonable to assume that much of the international evidence - especially from similar economies such as the US, UK and Canada - would be applicable to Australia.

The evidence from our review reflects a mix of quantitative and qualitative research findings. Additional details of the studies reviewed are available in the *Evidence Tables* at Appendix A-C and is summarised below and set out in the body of the Report under *Research Questions 1-4* each of which is structured into four sections:

- a brief introduction
- a summary of the key findings
- a detailed description of the evidence
- authors' comments

Summary of key findings for Research Question 1 – Health harms

Adults in coal mining communities have been found to have:

- Higher rates of mortality from lung cancer, chronic heart, respiratory and kidney diseases
- Higher rates of cardiopulmonary disease, chronic obstructive pulmonary disease (COPD) and other lung diseases, hypertension, kidney disease, heart attack and stroke, and asthma
- Increased probability of a hospitalisation for COPD (by 1% for each 1,462 tons of coal mined), and for hypertension (by 1% for each 1,873 tons of coal mined).
- Poorer self-rated health and reduced quality of life

Children and infants in coal mining communities have been found to have:

- Increased respiratory symptoms including wheeze, cough and absence from school with respiratory symptoms although not all studies reported this effect
- High blood levels of heavy metals such as lead and cadmium
- Higher incidence of neural tube deficits, a high prevalence of any birth defect, and a greater chance of being of low birth weight (a risk factor for future obesity, diabetes and heart disease)

Adults (and whole population) in communities near coal-fired power stations and coal combustion facilities have been found to have:

- Increased risk of death from lung, laryngeal and bladder cancer
- Increased risk of skin cancer (other than melanoma)
- Increased asthma rates and respiratory symptoms

Children, infants, and fetal outcomes in communities near coal-fired power stations and coal combustion facilities have been found to have

- Oxidative deoxyribonucleic acid (DNA) damage
- Higher rates of preterm birth, low birth weight, miscarriages and stillbirths
- Impaired fetal and child growth and neurological development
- Increased asthma rates and respiratory symptoms.

Summary of key findings for Research Question 2 – Disease clusters in the Hunter Region

No specific research studies were found to confirm or refute the existence of mining related disease clusters among residents of the Hunter Region, or their possible causes if they do exist. In the absence of such evidence, we reviewed two reports of routine health monitoring data from the Hunter Region from the NSW Health Department (now known as the NSW Ministry of Health). These reports showed mixed results. For example, the NSW Health Report (2010a) included the whole of the Hunter Region and suggested higher rates of deaths and illness in some areas for some health problems when compared with the rest of NSW. However, the *Bettering the Evaluation and Care of Health* (BEACH) general practice data for Singleton, Muswellbrook and Denman postcodes (NSW Health 2010b) did not demonstrate significantly higher rates of any problems managed, or medications prescribed or supplied, in general practice compared with the rest of non-metropolitan NSW.

Summary of key findings for Research Question 3 – Social injustice (other than in the Hunter Region)

For the purposes of this report, we defined social injustice as: '*the unequal or unfair social distribution of rewards, burdens, and opportunities for optimising life chances and outcomes'*. This definition includes unfair imbalances in access to essential natural resources, opportunities for employment, education, political or social power and influence, and social or individual burdens such as financial costs, social or occupational disruption, and environmental damage.

Aside from studies focussing explicitly on the Hunter Region of NSW which are discussed in the next section, six peer reviewed articles were identified from the US, the UK, Russia and (Queensland) Australia that directly addressed social injustices associated with coal mining. While there were limitations to these, a central theme of the impact on local communities was both real and perceived environmental degradation and injustices. We categorised the evidence for social injustice as:

- **Environmental damage and perceptions of damage and health impacts**
  - slurry (fly ash) spills
  - lack of community awareness of damage
  - distress resulting from concerns and uncertainties about the health impacts of mining-related pollution

- **Water quality and human occupations (activities)**
  - The impact of water pollution on securing safe water for drinking, producing food, swimming and fishing

- **Social and economic costs**
  - the cost of environmental damage to communities and society
  - inability of the community to capture economic benefits
  - social changes inhibiting the generation of alternative means of economic capital to mining
  - socio-demographic changes resulting in labour shortages in other industries; reduced access to and affordability of accommodation; increased road traffic accidents
  - increased pressure on local emergency services
  - increases in criminal and other anti-social behaviours.

Summary of key findings for Research Question 4 – Social injustice in the Hunter Region

Six peer reviewed studies were identified on social aspects of mining in the Hunter Region. These studies detail a variety of impacts such as:

- **Social distress and environmental injustice** including concerns over the cumulative health impacts of mining, social divisions and inequalities, feelings of loss and disempowerment, pollution/poor air quality, environmental damage and the potential to impact negatively on future generations

- **Asymmetry of power and influence** including access to information, contestation over natural resources, and political conflicts of interest

- **Water access and rights** including changes to the NSW water grading system favouring the coal mining industry

- **Failure to protect** - specifically, the failure of government and the mining industry to exercise the precautionary principle and protect local communities from potential or actual harms.

Authors' comments

The evidence presented in this report is valid and objective. However, it is acknowledged that there are limitations to many of the studies cited. It should also be noted that there are inherent difficulties in designing population and community studies that can unequivocally attribute and precisely quantify associations. Conversely, there is a lack of long term prospective studies on the effect of coal mining and coal-fired power stations on local communities which may lead to potential causal associations between mining activity and diseases with a long time lag such as cancers to be underestimated.

Studies of air pollution were excluded from the review if the study did not specify coal mining or combustion as the pollution source. This may mean that death and illness in local communities due to coal dust may be underreported. Similarly several studies which found airborne toxins and pollutants known to be harmful to health in areas surrounding coal mines, coal washeries and power-plants were not included as evidence as they did not link their results to health outcomes. Further, some of the studies we reviewed on the health of local communities, including in the Hunter and surrounding areas, were conducted up to 20 years ago and it could be assumed that the huge expansion in coal mining over that period may have amplified any health impacts.

Given that there is minimal research evidence available on the health impacts of coal mining and combustion on Australian communities, the vast majority of the evidence cited in this Report is from international studies conducted in a variety of countries. While some of these countries (US, UK, Canada) share a similar cultural ethos and are economically and politically comparable, there is considerable variation in mining practices and regulatory standards between countries that needs to be taken into account when extrapolating the evidence from one country to another. There are also differences in techniques and tools for monitoring air quality which make comparisons difficult. However, emerging methods for measuring exposures are becoming increasingly accurate and replicable, thus measurement inconsistencies will likely be much less problematic in the future.

Costs and policy implications of coal mining

The financial and social costs of coal mining and combustion are enormous and may well outweigh any benefits (Hendryx & Ahern, 2009). According to one report (ATSE, 2009), health problems associated with coal-fired power stations cost Australia $2.6 billion(AUD) annually. Burdens on the whole society such as government subsidies and benefits to the mining industry were recently detailed in a report by the Australia Institute and are rarely included in cost calculations (Richardson & Denniss 2011). Further, there is evidence from the international literature of the cost burden of environmental damage resulting from mining falling disproportionately on society rather than the industry.

These impacts have wide implications for policy and governance, and require prompt and thorough attention to reviewing and reforming government policies and regulations around the licensing and operating of coal mines and coal-fired power stations. While awaiting such reforms there is an urgent need for a policy response to ensure transparency in arrangements between government and the mining industry, redress tax anomalies, enforce standards of practice and community safeguards such as mandatory health impact assessments and penalties for non compliance with operating standards and regulations.

Most importantly, evidence from well designed local studies capable of accurately quantifying associations are required to underpin cost analyses and inform public and political debate and decisions about the balance of benefits and harms of coal mining activity, and guide policy and planning to minimise the harms and maximise the benefits.

Section 1:

THE CONTEXT

INTRODUCTION & RATIONALE

About coal mining

Australia is the largest coal exporter worldwide, exporting millions of tonnes annually and around 85% of Australian energy consumption comes from coal. For black coal alone, Australia's saleable production totalled 326.8 million tonnes in the 2007-08 financial year (Australian Department of Resources Energy and Tourism, 2011).

In recent years, the seemingly ever-increasing demand for coal to build and fuel Asia's rapidly growing cities and industries, especially China's, has resulted in massive increases in Australian coal production as has the need to power our own growing cities, towns and technologies. Concerns that the world has passed peak oil production, along with the increasing cost of oil compared with the relatively low cost of coal, and its importance to the manufacture of steel, have also driven recent demand.

New South Wales and Queensland (QLD) contain the majority of Australian coal reserves with other states, notably Victoria and Western Australia, also having sizeable deposits. The Sydney-Gunnedah basin, including the Hunter Region, holds almost all the coal resources in NSW with smaller quantities in the Gloucester and Oaklands basins. Recoverable coal reserves in NSW are estimated at 12 billion tonnes, and are contained within 60 operating mines and more than 30 major development proposals (NSW Department of Primary Industries, 2011). So, although as a nation, we must ultimately come to terms with the inevitable fact that our coal reserves are finite, and it appears that further expansion is likely before the current boom is over.

The Australian Coal Association describes two main methods of extracting coal ie i) underground or so-called deep mines and ii) open-cut mines which are often called open-cast or surface mines. The method is selected according to the distance (depth) of the coal seam from the land surface with underground mining accounting for the majority (approximately two thirds) of coal production worldwide. However, this figure is much lower in Australia where surface (open-cut) mining is relatively and increasingly, common - possibly because it yields a greater proportion of the coal deposit than underground mining (Australian Coal Association, 2008). The majority of coal mines in the Hunter Region are open-cut. In the US a third method is sometimes used whereby mountain tops situated over coal deposits are removed and deposited in the valleys below. This method is thought to pose additional risks to health and the environment over and above those associated with open-cast mining.

The role and impact of coal on society and the environment

Coal has been an important building block in human advancement throughout modern history. For example, coal powered the industrial revolution and, in doing so, opened up new and previously unimaginable changes to the way humans live, move around the world, communicate and do business, and provide life saving health care and technologies. But, there is a downside and, opponents argue that the benefits of coal mining come at a cost - to the communities in which coal mines and power stations operate, and to the nation as a whole.

The economy

Industry proponents claim that coal mining fuels economic growth and brings wealth and prosperity, creating jobs and reinvigorating rural and regional Australia, enhancing local quality of life and opportunity. However, Richardson & Denniss (2011) claim that around 80% of the profits go to foreign owners and investors and estimates of the contribution of coal to Australia's gross domestic product (GDP) vary considerably but seem to centre around 3-4%. There are also criticisms of the 'boom and bust' nature of mining based economies, and the relatively small numbers (circa 60,000 people) currently employed in the Australian mining industry.

The environment

Many reports, both formal and anecdotal, note the irreparable scarring of landscapes, soil degradation and the depletion of habitat and biodiversity as serious negative impacts of coal mining. In addition to direct damage to the natural environment, coal combustion makes a major contribution to generating greenhouse gasses (GHG). For example, in 2005 coal contributed 25% of global energy consumption but almost half (41%) of carbon dioxide (CO_2) emissions that year (Epstein et al, 2011). Since coal was reported in 2008 as contributing 40% of global electricity alone (Australian Coal Association, 2008), it might be assumed that resultant global CO_2 emissions have increased commensurately with the demands imposed by global population growth and urbanisation in the intervening years.

Air and water pollution and other health impacts

Coal mining generates dust and noise from blasting and operations, particularly from open-cast mining. Onder & Yigit (2009) claim that all major open-cast mining operations produce dust as a result of blasting, drilling, loading/unloading and transporting. Several studies cite coal washeries as creators of further dust exposure, and the heavy machinery required in mining generally uses industrial diesel fuels and may be noisy as well as producing harmful fumes. Coal burning generates a variety of pollutants; depending on the composition of the coal, and the measures taken to control emissions. Emissions may include heavy metals, potential carcinogens such as polyaromatic hydrocarbons (PAHs), sulphur dioxide (SO_2) and nitrous oxides (N_2O) and fine particulate matter - especially particulate matter 2.5 micrometers or less in diameter ($PM_{2.5}$) which is more closely associated with adverse health effects than larger particulate matter 10 micrometers or less in diameter (PM_{10}) (Lockwood et al, 2009). These pollutants may spread widely and coal burning in the Northern Hemisphere has reportedly left a toxic heavy metal legacy in the Arctic. Examination of heavy metal deposits of thallium, cadmium and lead from a Greenland ice core identified coal burning in Europe and North America as the likely sources dating from 1860 onwards (Mc Connel & Edwards 2008).

Combustion waste products (fly ash) also pose health risks. Storage of these wastes is problematic and accidental leakage can cause the release of toxic pollutants. For example the 2008 Tennessee Valley Authority fly ash spill in the US resulted in 1 billion gallons of fly ash slurry containing contaminants spreading over 300 acres, and leaking into local rivers and household wells (Epstein et al, 2011). Coal combustion by-products are sometimes used as building materials which may also be associated with health hazards. Further, Castledon and colleagues (2011) cite evidence that 53 people were killed in Kentucky (US) mining areas and 536 injured from 2000-04 in accidents involving coal transport vehicles.

Social harms

Epstein and colleagues (2011) claim that all stages of the life cycle of coal pose potential risks to human health and wellbeing. Some of these risks and harms take the form of social injustices which, for the purpose of this report, we define as the ‘unequal or unfair social distribution of rewards, burdens, and opportunities for optimising life chances and outcomes’. These are of central concern in the current debate about mining in Australia.

Purpose of the Report

This Report was commissioned to examine and summarise what is known in the available evidence from Australian and international health journals, and other reports, about the health and social harms of mining activity for communities living in or near coal mines and coal-fired power stations. This includes a ‘spotlight’ on the Hunter Region of NSW - Australia’s oldest and one of its most active coal mining areas.

ABOUT THE HUNTER REGION

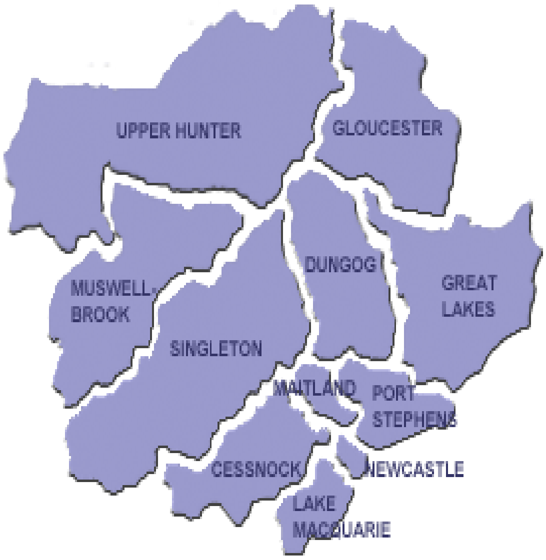
The Hunter Valley lies 160 kilometres north of Sydney. As with many of Australia's rural areas, the majority of its almost 700,000 strong population resides in the area's largest urban centre, in this case, the Newcastle Metropolitan Area. The Hunter Region contains the Hunter River and its tributaries with highland areas to the north and south and is one of the largest river valleys on the NSW coast. Table 1 shows the 11 Local Government Areas (LGAs) included in the Hunter Region and the population by LGA. The map shown in Figure 1 indicates the configuration of the Hunter Region LGAs.

Table 1: Population of the Hunter Region by Local Government Area

Local Government Area	Population in 2010
Cessnock City Council	51 706
Dungog Shire Council	8 673
Gloucester Shire Council	5 181
Great Lakes Council	35 924
Lake Macquarie City Council	200 849
Maitland City Council	70 296
Muswellbrook Shire Council	16 676
Newcastle City Council	156 112
Port Stephens Council	67 825
Singleton Council	24 182
Upper Hunter Shire Council	14 198
TOTAL	**651 622**

Source: Australian Bureau of Statistics, 2011. National Regional Profile 2006-2010.

Figure 1: Map of Local Government Areas in the Hunter Region



Source: New South Wales GenWeb Project, 2011. Hunter Valley GenWeb.

Newcastle is home to the biggest black coal exporting port in the world

Industries

Mining is only one of several important industries currently operating in the Hunter Region. A major issue in the current mining debate centres on contention over what is the most appropriate use of available natural resources (land and water) and the impact of mining activity on other local industries such as grazing, farming, race horse breeding, wine growing, and tourism.

Coal mining

As the site of the initial discovery of coal in Australia in 1791, the Hunter Region has a long history of mining. Over the past 30 years, there has been a sixfold increase in coal production and more mines or expansion of existing mines have been proposed. Table 2 shows the number of coal-fired power stations and the number, location and type of coal mines operating in the Hunter Region and adjacent coalmining area (Gunnedah) in 2009. The areas with the most intensive coal mining and power generation activities include the Upper and Lower Hunter clusters, and the Muswellbrook and Singleton LGAs. Despite the vastly increased production of coal, the numbers employed in the mining industry are less than in the 1970s, due to increased mechanisation, and account for about 8% of the jobs in this region.

Table 2: Operating coal mines in the Hunter Region and adjacent coal mining areas

Coalfield Region	Coal-Fired Power Stations	Coal Mines		
		Open-cut	Underground	Combined (open-cut & underground)
Hunter	3	12	2	4
Newcastle	3	5	9	-
Gunnedah	-	4	-	-
TOTAL	**6**	**21**	**11**	**4**

Source: NSW Department of Primary Industries, 2009. 2009 New South Wales Coal Industry Profile.

Around 75% of the coal mined in the Hunter Region and adjacent areas is for export and the largest black coal exporting port in the world is located in Newcastle.

Agriculture

The Hunter Region is adjacent to the Liverpool Plains which is considered a prime agricultural region of NSW. It comprises 1.2million hectares which produce 37% of the nation’s cereal crop and is an important ‘food bowl’ for Sydney and other parts of NSW and Australia. As demand grows and issues around food security increase, the sustainability of the Hunter and Liverpool Plains regions is critical to Australia’s population carrying capacity. Approximately 4,000 people are employed in the agriculture, fishing and forestry sector in the Hunter Region and the gross value of its agricultural production was about $382 million(AUD) in 2008-09, accounting for just over 4% of the total value of agricultural production for NSW (Thompson et al, 2011). Of the total agricultural production in the Hunter Region beef cattle were the most important produce, accounting for 37% ($140million AUD); followed by poultry at 26% ($100million AUD). The dairy industry also played a major role accounting for approximately 17% ($64million AUD).

Winemaking

The Hunter Region is one of Australia’s oldest wine producing areas and a principal winemaking area of NSW, producing 25.4million litres of wine per year valued at approximately $203million(AUD) annually (NSW Department of Trade and Investment, 2012). Viticulture and winemaking are a significant component of the Hunter Region’s agricultural industries, with wine-grape farms accounting for 5% (145 farms) of total farms in 2008-09 (Thompson et al, 2011).

Race horse breeding

The Upper Hunter Valley is not only Australia's main region for breeding thoroughbred horses (approximately 70%) but is one of the largest in the world. Australia's thoroughbred breeding and racing industry contributed sustainable employment of over 65,000 people - especially in regional Australia; over \$5.04billion(AUD) in value added to the national economy; investment of \$1.1billion(AUD) annually by breeders owners and trainers; and exports of over \$750 million(AUD) to 24 countries (Biopharm Australia, 2011) This industry relies on a certain rural attractiveness which co-exists along with local agribusiness industries such as dairy farming and winegrowing.

Tourism

Also heavily dependent on rural attractiveness, the Hunter Valley is a prime tourism location. According to a submission by Doctors for the Environment Australia (2011) statistics for the Hunter Region for 2008-09 estimate that \$1.3billion(AUD) was spent by visitors - 58% by domestic overnight visitors. A total of 6.3 million visitors went to the region – 68% were domestic day visitors. Fifty three per cent of domestic visits and 93% of international visits were related to food and wine. Fourteen per cent of domestic visits and 74% of international visits were related to nature-based activities (Tourism Research Australia, 2010).

Health service provision and monitoring

For the purpose of planning and providing health services and monitoring the health of the NSW population, the LGAs of the Hunter Region fall within what was, until recently, called the Hunter New England Area Health Service (HNEAHS). HNEAHS is one of several Area Health Services (geographically determined health administrative entities which were recently renamed Local Health Districts) in NSW. It covered 25 LGAs, 11 of which constitute the Hunter Region. HNEAHS is responsible for administration of local public hospital and community health services. In 2010 The NSW Health Department (recently renamed the NSW Ministry of Health) published a report entitled *Respiratory and Cardiovascular Diseases and Cancer in Residents of the Hunter New England Area Health Service* (2010a). Data from the NSW Health Report is cited in detail later in this document and provided the information below.

Smoking

Smoking rates for the background population need to be taken into account when analysing death or illness and disability for lung cancer or other respiratory diseases, as this could be a confounding factor in attributing cause and effect for airborne pollutants and toxins. The NSW Health Report (2010a) indicates that the overall self-reported smoking rate for HNEAHS (19.3%) is similar to that for NSW (19.2%). There is no significant difference in smoking rates across areas within the HNEAHS.

Drinking Water Quality

In accordance to National Health & Medical Research Council Drinking Water Guidelines, the NSW Health Drinking Water Monitoring Program specifies the number of samples that should be taken and tested for a range of chemicals. The NSW Health Report (2010a) indicates that the drinking water supplies for the towns near extensive open-cut mining and power generation activities are of comparable quality to that of other rural town water supplies. The quality of water in domestic rainwater tanks in NSW is not routinely monitored.

Socioeconomic status

The 2010 NSW Health Report also commented on socioeconomic disadvantage, another potential confounder for certain health outcomes particularly where there is a higher Aboriginal population, public housing and lower employment. Only Cessnock was listed among the 10 most socioeconomically disadvantaged LGAs in the HNEAHS.

Section 2:

SCOPE & METHODS

SCOPE OF THE REVIEW

The project brief

This Report deals exclusively with the effects of open-cut and underground coal mining and coal-fired power stations on local communities.

Commissioned by Beyond Zero Emissions, the project brief was to provide an objective overview of the international and local evidence from the health and medical literature about the health and social impacts of coal mining activity on local communities, highlighting those areas and aspects of the findings that were generated in, or can be extrapolated to current and planned mining activities in the Hunter Region.

The Report does not consider the occupational health and safety aspects of mining ie the health of mine workers. Nor does it consider the health consequences and implications of alternatives to coal such as coal seam gas or wind farming.

There is a sizeable international and national literature about the health effects of air pollution. Coal mining (particularly where open-cut methods of extraction are used), burning coal in coal-fired power stations and associated activities can contribute substantially to air pollution. However, there are also a number of other common sources of air pollution exposure such as vehicle exhaust fumes for communities living adjacent to major roadways. It should be noted that this review did not consider articles in which the source of air pollution was not clearly attributable to coal mining activity or where the pollution source was not stated.

Aims

Specifically, we aimed to:

- Undertake a rapid review of the available evidence about the health and related social harms of mining in local communities, drawing on the national and international peer reviewed health literature and relevant government and non-government reports

- Map any real or perceived ‘hotspots’ for mining related diseases and health problems in the Hunter Region of NSW, and comment on the outcomes

- Develop a report that identifies the significant, cumulative health impacts and major social impacts and trends associated with coal extraction and power generation in the general community/s living in the proximity of coal mines and/or coal-fired power stations.

METHODS

A narrative review of the relevant national and international peer reviewed press, and reports and websites of government and non-government organisations was conducted.

Research questions and information sources

The methodological framework was built on four research questions ie:

1. What specific diseases or other health problems are associated with coal mining in local communities?
2. Are there clusters of these diseases or other health problems in the Hunter Region of NSW?
3. Is social injustice associated with coal mining in local communities?
4. Is there an association between coal mining and social injustice in the Hunter Region of NSW?

Articles from the peer reviewed medical and health literature were accessed through the University of Sydney Library and sourced from searches of the following health databases.

- Cochrane Library
- Medline
- Psychinfo
- Embase
- Pre –Medline
- CinHal

Technical reports and non-peer reviewed articles were accessed via web searches of relevant government and non-governmental organisations, and centred predominantly on Australia.

Searching and sorting the literature

The searches were jointly conducted by two members of the project team. Articles and technical reports were selected for the evidence review on the basis of pre-determined inclusion and exclusion criteria.

Journal articles and reports were included in the evidence review if they met the following criteria:

- addressed one or more of the research questions and were published in English
- reported on/involved humans living or working in local communities near coal mines
- were published during or since 1990 up to mid 2011
- included or were relevant to communities in the coal mining areas of NSW

Journal articles and reports were excluded from the evidence review if they:

- did not meet the inclusion criteria
- focussed on coal mining related occupational exposures, injury or accidents
- focussed on exposures to domestic coal use (cooking, heating)
- reported on air pollution without specifying the relative contribution of coal mining activity

Reviewing and synthesising the relevant literature

The research team reviewed and summarised the included papers and reports according to a standardised review guide ie the Johanna Briggs Institute Reviewers’ Manual: 2008 Edition. More than 50% of the articles included in the report were reviewed by two members of the research team. The summaries were then collated by the authors to form a response to the research questions.

Section 3:

THE EVIDENCE

Research Question 1

What specific diseases or other health problems are associated with coal mining in local communities?

> **"Each step of the coal life cycle: mining, transportation, washing, combustion, and disposing of post-combustion wastes has impacts on human health" Epstein et al, 2011.**

Introduction

There have been few Australian studies that directly assess the health effects of coal mining or coal combustion in coal-fired power stations on the health of people living in surrounding communities. However, evidence from the international literature indicates that coal mining communities are at an increased risk of developing cardiopulmonary (heart/lung) disease, chronic obstructive pulmonary disease (COPD), other lung diseases, cancer, hypertension (high blood pressure), and kidney disease. Mortality rates for these diseases were higher in communities living in proximity to coal mines and coal-fired power stations.

We identified 38 relevant peer reviewed journal articles reporting on studies of the effects of coal mining and coal combustion on the health of local communities. Several of these studies are from the coal mining areas of West Virginia and Appalachian counties in the US, other parts of the US, and from Australia, Canada, the UK, Spain, Croatia, Poland, Slovakia, Turkey, Israel, China, Taiwan and Thailand. Three Australian studies from NSW were also included but were not recent, having been conducted around 20 years ago. A combined summary and detailed descriptions of each of the individual studies reviewed are reported below and further summarised in the Evidence Table in Appendix A. The evidence summary set out below is structured under the broad headings of:

- Coal mining
- Coal combusting power stations.

Under these two main headings, where possible, the evidence us further separated and reported under the following sub-headings:

- Adults
    - mortality (death)
    - morbidity (illness and disability)
    - hospitalisation
    - quality of life
- Children, infants, and fetal outcomes
    - respiratory disease
    - toxins
    - birth defects
    - fetal and infant growth and development

These categories were generated from the literature rather than by pre-determined by the authors of this Report.

Summary of Key Findings for Research Question 1

The available evidence indicates that there are negative health impacts for people living in communities near coal mines and coal combusting power stations. Much of the evidence comes from the Appalachian region of the US, where coal mining has been conducted for many years and which has higher morbidity and mortality rates than the rest of the US.

Evidence from the Appalachian studies along with evidence from other US studies, Australia, Canada, the UK, Slovakia, Croatia, Turkey, Israel, China, Taiwan and Thailand indicates that environmental exposure to particulate matter or toxic agents present in coal and released in coal mining and processing, and water contamination with toxicants found in coal and coal processing have been linked with health harms.

Health harms associated with coal mining

Adults in coal mining communities have been found to have:

- Higher rates of mortality from lung cancer, chronic heart, respiratory and kidney diseases
- Higher rates cardiopulmonary disease, chronic obstructive pulmonary disease (COPD) and other lung diseases, hypertension, kidney disease, heart attack and stroke, and asthma
- Increased probability of a hospitalisation for COPD (by 1% for each 1,462 tons of coal mined), and for hypertension (by 1% for each 1,873 tons of coal mined).
- Poorer self-rated health and reduced quality of life

Children and infants in coal mining communities have been found to have:

- Increased respiratory symptoms including wheeze, cough and absence from school with respiratory symptoms - however, not all studies reported this effect
- High blood levels of heavy metals such as lead and cadmium
- Higher incidence of neural tube deficits, a high prevalence rate of any birth defect, and a greater chance of being of low birth weight (a risk factor for future obesity, diabetes and heart disease).

Health harms associated with coal combusting power stations

Adults (and whole population) in communities near coal-fired power stations and coal combustion facilities have been found to have:

- Increased risk of death from lung, laryngeal and bladder cancer - particularly if living close to the plant
- Increased risk of skin cancer (other than melanoma) possibly due to exposure to arsenic
- Increased asthma rates and respiratory symptoms due to air pollutants and particulate matter

Children, infants, and fetal outcomes in communities near coal-fired power stations and coal combustion facilities have been found to have:

- Oxidative DNA damage possibly due to exposure to carcinogenic chromium and arsenic from coal combustion
- Higher rates of preterm birth, low birth weight, miscarriages and stillbirths associated with products of coal combustion, specifically sulphur dioxide
- Reduced fetal and child growth and neurological development associated with elevated levels of polycyclic aromatic hydrocarbons, of which power stations are a significant source
- Increased asthma rates and respiratory symptoms due to air pollutants and particulate matter.

Detailed Description of the Evidence for Research Question 1

A: COAL MINING - Adults

Mortality (death)

Hendryx and Ahern (2008) used census, geographical and environmental data for West Virginia, and cancer mortality rates from the US Centres for Disease Control to determine if residing in a coal mining county of Appalachia was an additional risk factor for mortality from lung cancer. The results of this retrospective analysis demonstrated that, after adjusting for confounding factors, lung cancer mortality was higher in areas of heavy coal mining. The effect of the coal mining exposure was significant for all levels and for both specifications of exposure used in the study (tonnage in millions and per capita exposure in tons), except for the lowest level in ton per million.

Another study in the same region aimed to determine if population mortality rates from heart, respiratory and kidney disease were higher as a function of the quantity of coal extracted (Hendryx, 2009). Four groups of counties were compared:

- Appalachian counties extracting more than four million tons of coal
- Appalachian counties extracting less than four million tons
- non-Appalachian counties with coal mining
- counties where there was no coal mining

Chronic heart, respiratory and kidney disease were compared with acute episodes of the same diseases. The results demonstrated that mortality rates in Appalachian counties extracting the largest quantities of coal were significantly higher than in non-mining areas for chronic heart, respiratory and kidney disease. Higher rates of acute heart and respiratory mortality were found for non-Appalachian coal mining counties. The authors concluded that higher chronic disease mortality in coal mining areas may partially reflect environmental exposure to particulate matter or toxic agents present in coal and released in its mining and processing.

In a subsequent study, Hendryx and colleagues (2010) compared cancer mortality rates using two different methods for calculating mining exposure. These were the Geographic Information Systems (GIS) method (a measure based on location of mines, processing plants, coal slurry impoundments and underground slurry injection sites relative to population levels) and a measure of exposure based on tons of coal mined. The GIS method is believed to be a more sensitive measure for calculating mining exposure for health impact purposes. The results of this study indicated that total, respiratory, and other age-adjusted cancer mortality rates in West Virginia were more closely associated with the GIS-exposure measure than tonnage measure of exposure. This effect was observed both before and after controlling for smoking rates.

Assessments of ecological integrity are commonly used in biological conservation but have been largely unused in public health. A study by Hitt and Hendryx (2010) tested the ecological integrity of streams in West Virginia, US, using the Stream Condition Index (SCI) to determine if such a methodology could be an indicator of human cancer mortality rates. The authors found as the SCI scores worsened, age-adjusted total cancer mortality increased. Respiratory, digestive, urinary, and breast cancer rates also increased with ecological disintegrity but genital and oral cancer rates did not. Coal mining was significantly associated with ecological disintegrity and higher cancer mortality and spatial analyses indicated cancer clusters that corresponded to areas of high coal mining intensity. The results from this study demonstrate significant relationships between ecological disintegrity and human cancer mortality in West Virginia.

Cardiovascular disease (CVD) mortality rates within Appalachia are comparatively higher than the rest of the US. Esch and Hendryx (2011) conducted a study to determine if there were differences in chronic CVD mortality rates (ie excluding acute CVD events) relating to the presence or absence of coalmining and/or the method of coal mining. The study also aimed to determine if there was an association between the total surface area of mining and CVD mortality rates. Age-adjusted CVD mortality rates from three counties were compared for residents of:

- mountain top coal mining areas
- non-mountain top mining areas
- non-mining areas

Mortality rates were found to be significantly higher in both categories of mining areas compared with non-mining areas but were highest in mountain top mining areas. Additionally, CVD mortality rates in mountain top mining areas were found to be related to the level/extent of surface mining.

Veugelers and Guernsey (1999) evaluated mortality patterns (focusing on life expectancy and life loss) for Cape Breton County, a coal mining area of Nova Scotia, Canada over five decades. Life loss refers to the difference in life expectancy of Cape Breton County residents and all Canadians. The study area, Cape Breton County, contains one of the most polluted areas in North America and is socioeconomically depressed. The data demonstrated that life expectancy in some municipalities of Cape Breton County was reduced by more than five years. Life loss for these residents was greater than for any single cause of death for Canadians overall. Life loss among Cape Breton County men was primarily attributable to CVD but among women it was primarily related to cancer. Life loss from all types of cancer was higher in the steel-producing communities whereas life loss from respiratory diseases and lung cancer was higher in the coal mining communities. The authors suggest that these differences may relate to environmental and occupational exposures associated with local coal mining, as well as to socioeconomic status and smoking rates.

Morbidity (illness and/or disability)

Hendryx and Ahern (2008) conducted a telephone survey and analysed self-reported presence or absence of specific health conditions in almost 16,500 West Virginian adults. They compared the data from the telephone survey with county-level coal production figures to investigate the relationship between health indicators and residential proximity to coal mining. The results indicated that, after controlling for possible demographic and social confounders, high levels of coal production were associated with worse health status and with higher rates of cardiopulmonary (heart/lung) disease, hypertension, lung disease, and kidney disease.

In a later study, Hendryx and Zullig (2009) analysed the US 2006 Behavioural Risk Factor Surveillance System (BRFSS) survey data (n = 235,783) to determine whether self-reported CVD rates were higher in Appalachian coal mining counties compared with other counties. After controlling for variables, the authors found that people in Appalachian coal mining areas reported a significantly higher risk of CVD, angina or coronary heart disease, and heart attack. These effects were present for both men and women, and the authors concluded that CVD is linked to both air and water contamination in ways consistent with toxicants found in coal and coal processing.

In response to government concerns regarding excess prescribing for asthma, a Welsh general practice (UK) audited its patient and treatment records for new asthma episodes (Temple & Sykes, 1992). A statistically significant increase in the number of weekly asthma episodes was evident from the audit following the opening of a nearby open-cast coal mine, even after controlling for seasonal and other transient factors.

Hospitalisation

In a retrospective analysis, Hendryx and colleagues (2007) investigated whether the volume of coal mining was related to population hospitalisation risk for diseases postulated to be sensitive or insensitive to coal mining by-products. Adult hospitalisation data from the records (n = 93,952) of 90 hospitals across West Virginia, Kentucky, and Pennsylvania (US), were merged with county-level coal production figures. After controlling for confounding variables, the results showed that the volume of coal mining was significantly related to hospitalisation risk for COPD and hypertension. The probability of a hospitalisation for i) COPD increased by 1% for each 1,462 tons of coal mined, and ii) for hypertension by 1% for each 1,873 tons of coal mined. Other conditions were not related to mining volume. This study indicates that exposure to particulates or other pollutants generated by coal mining activities is linked to increased risk of COPD and hypertension hospitalisations.

Quality of life

Zullig and Hendryx (2010), examined health-related quality of life (HRQOL) in mining and non-mining counties in and outside the Appalachian region of the US using the BRFSS survey (n = 349,247). Residents of coal mining counties, both in and outside Appalachia, reported significantly fewer healthy days for both physical and mental health, and poorer self-rated health when compared with non-coal mining counties. Disparities were greatest for people residing in Appalachian coal mining areas. The authors note that self-rated health has proven to be a more powerful predictor of mortality than detailed objective, physician-assessed health indicators. Thus, the persistent effect on impaired self-rated health among residents of Appalachia, and among residents in coal mining counties outside of Appalachia, support studies that have documented increased mortality associated with coal mining.

The health related quality of life (HRQOL) of residents in mountain top mining counties of Appalachia was examined more specifically in a subsequent study using the BRFSS survey results (Zullig & Hendryx, 2011). Data from 10,234 residents in three geographic areas were compared ie:

- mountain top coal mining areas
- non-mountain top mining areas
- non-mining areas

Residents of any coal mining areas were found to have significantly more days of poor physical, mental and activity limitation, and poorer self-rated health compared with residents of non-mining counties. Reductions in HRQOL were greatest for those residing in mountain top mining areas. These findings confirm the negative impact of mining activity generally on quality of life for local residents and suggest that the unique contribution of mountain top mining activity is responsible for the greatest negative effect.

B. COAL MINING – Children and infants

Respiratory disease

Brabin and colleagues (1994) conducted a cross-sectional survey of parents, using a questionnaire, to determine if school children in a specific locality exposed to pollution from steam coal dust have more respiratory symptoms compared with children in control areas. A total of 1,872 primary school children (aged 5-11 years) from five primary schools in the Bootle dock area of Liverpool in the UK (exposed area) were compared with five primary schools in South Sefton (control area) and five primary schools in Wallasey (control area). The two selected control groups, located 3-8km from the coal terminal, were demographically similar. Analysis of the results showed that respiratory symptoms were significantly more common in the exposed area, including wheeze, excess cough, and school absences for respiratory symptoms. These differences remained significant even when parental employment and smoking status were taken into consideration. A further analysis confirmed, after adjusting for confounding factors, that the exposed zone was a significant risk factor for absenteeism from school due to respiratory symptoms.

This study confirmed an increased prevalence of respiratory symptoms in the primary school children exposed to coal dust.

Two studies examined whether living near open-cast mines affects acute and chronic respiratory health in children (Pless-Mulloli et al, 2000; Pless-Mulloli et al, 2001). Children, aged 1-11 years, from five socioeconomically matched pairs (exposed/control) that resided in rural and semi-urban communities in Northern England were selected to participate. Patterns of the daily variation of particulate matter 10 micrometers or less in diameter (PM_{10}) were not statistically different in open-cast and control communities but there was a tendency for PM_{10} to be higher in open-cast areas. Open-cast sites were also a measurable contributor to PM_{10} in adjacent areas. However, associations between daily PM_{10} concentrations and acute health events were similar in open-cast and control communities. Not surprisingly, little evidence was found of associations between living near an open-cast site and an increased prevalence of respiratory illnesses or asthma severity, but children in four out of the five open-cast communities had significantly more respiratory consultations than children in control communities. There was considerable unexplained variation in some health outcomes (such as the use of asthma medication, the number of severe wheezing attacks in the past year and tonsillitis) without a discernible pattern. The studies concluded that although children residing in close proximity to open-cast mines were exposed to a small but significant amount of additional PM_{10}, past and present respiratory health was similar. The authors proposed that the apparent contradictory results were due to the level of variation between communities and pairs, even though community pairs were well matched for lifestyle and socio-economic factors. It may also be possible that there was insufficient difference in the density of particulate matter between the study and the control areas to cause detectable differences.

Toxins - lead and cadmium levels

A Turkish study in the coal mining area of Yatagan, in Western Turkey, investigated asymptomatic lead poisoning prevalence and cadmium exposure in preschool children aged 6 months to 6 years (Yapici et al, 2006). In 85% of all children, the mean blood cadmium level was found to be at a level considered to be toxic. A negative association was found between age and blood lead and cadmium levels. While it was not possible to calculate what proportion of the biological lead and cadmium came from mining waste and what proportion came from other sources, such as paint and gasoline residue deposited in soil and air, the results indicate that asymptomatic lead poisoning and cadmium exposure are significant problems in children living in the Yatagan area.

Birth defects

Neural tube defects (NTDs) are a group of congenital malformations of the brain and spinal cord caused by failure of the neural tube to close shortly after conception. They are associated with infant death and major forms of permanent disability such as spina bifida.

A spatial analysis of NTDs was carried out in the rural coal mining area of Heshun, Shanxi Province, China (Liao et al, 2010). The Shanxi province provides 25% of China's coal production and 5.6% of world production. This region has one of the highest reported prevalence rates of NTDs in the world, due in part to socioeconomic factors, soil type distribution and a complicated geological background. The study investigators tested whether residence in a coal mining area was an additional risk factor for a NTD. A cluster of NTDs was detected within six kilometres of the coal mines for almost every year during a seven year study period. An analysis revealed that there may be an association between production in coal mines and prevalence of NTDs in coal mining areas. A concern expressed by the authors was that there may have been a significant amount of under-reporting, as not all the birth records were complete. The authors surmised that there is a possibility that environmental contamination from the coal mining industry causes NTDs.

Two studies from Appalachia looked at birth outcomes (Ahern et al, 2011a; Ahern et al, 2011b). The first retrospectively examined birth defects in mountain top coal mining areas and compared these with other coal mining areas and non-mining areas of central Appalachia (n = 1,889,071) (Ahern et al, 2011a). Mountain top mining has been increasing in this area and results in greater environmental impacts than other types of open-cut mining. Statistical models that controlled for variables showed the prevalence rate for any birth defect was significantly higher in mountain top mining areas compared with non-mining areas but not in the non-mountain top mining areas. Birth defect rates were also significantly higher in mountain top mining areas for: circulatory/respiratory, central nervous system, musculoskeletal, gastrointestinal, urogenital, and 'other' defects. Elevated birth defect rates can be partly a function of socioeconomic disadvantage, but remained elevated after controlling for these factors. There was also evidence that the detrimental effects of mountain top mining were worsening and that they influenced birth defects in neighbouring counties.

The second study, was a cross-sectional, retrospective analysis to determine if there was an association between low birth weight (< 2.5 kg) and the mother’s residence in relation to coal mining areas in West Virginia, US (n = 42,770) (Ahern et al, 2011b). The study found, after controlling for confounders, that residing in coal mining areas of West Virginia posed an independent risk of low birth weight. Odds ratios suggested a dose-response effect meaning that, relative to counties with no coal mining, living in areas with higher levels of coal mining increased the likelihood of a low birth weight infant.

C. COAL COMBUSTING POWER STATIONS – Adults (and whole population)

Mortality, morbidity (illness and/or disability)

A Spanish study investigated whether there might be excess mortality from tumours of the lung, larynx and bladder in the population residing near Spanish combustion installations included in the European Pollutant Emission Register (García-Pérez et al, 2009). The results indicated that lung cancer mortality increased for all types of fuel used in power stations, whereas for laryngeal and bladder cancer the increase was only associated with coal-fired industries. Furthermore a relationship between cancer and proximity to combustion installations was found. From these outcomes, the authors concluded there is a significant association between risk of lung, laryngeal and bladder cancer mortality and proximity to Spanish combustion installations.

A case-control study was conducted to estimate the non-melanoma skin cancer (NMSC) risk associated with arsenic exposure from a coal-fired power station in the district of Prievidza, Slovakia (Pesch et al, 2002). The area studied currently has the highest incidence of NMSC in Slovakia. A significant risk between NMSC and arsenic exposure was found. The authors concluded that there is evidence of the impact of environmental arsenic exposure from power station emissions on NMSC development in the district of Prievidza.

Another study in the same area of Slovakia evaluated trends in the incidence of NMSC associated with arsenic exposure from the power station emissions from data collected over a 20 year time period (Bencko et al, 2009). Analysis of the data demonstrated a positive relationship between human cumulative exposure to arsenic and incidence of NMSC. Furthermore, the incidence of skin cancer showed an upward trend during the most recent five years of the study in the regions considered to be less polluted. The individuals living in this area had been exposed to lower levels of arsenic over a prolonged period of time suggesting that arsenic may have a cumulative effect on the incidence of NMSC.

The International Agency for Research on Cancer reviewed global cancer risks for the general population and occupational groups from the fossil fuel cycle, the nuclear fuel cycle, and renewable cycles (Boffetta et al, 1991). Cancer risks from waste disposal, accidents and misuses, and electricity distribution were also considered. The reviewers concluded that no cycle seems to be free from cancer risk. They also reported that cancer risks related to the operation of renewable energy sources were negligible, although there may be some risks from the construction of such installations. As the review is 20 years old, it is probable that possible carcinogenic outcomes from more recent energy cycles may have increased since the time of this publication.

A Turkish case-control study investigated the respiratory effects from the stack emissions of the Seyitömer coal-fired thermal power station in the Kütahya Province (Karavus et al, 2002). The exposed group was composed of residents from three villages within a five kilometre radius of the power station. They were compared with two demographically similar villages 30km away (control). People in the exposed group were found to have a statistically significant higher rate of complaints such as chest tightness and repeated coughing attacks present for more than one year. The results were however only significant above the age of 35 years. When further analysed, the respiratory parameters were worse in the exposed group for non-smokers, but not smokers. The authors concluded measures to prevent adverse pulmonary health effects caused by living near the power station are especially important for non-smokers. The Turkish power station is fuelled by lignite coals, which differ from those used in Australia so application of these results to the Hunter Region and other Australian coal mining areas may be limited.

A number of studies have investigated the health of people residing in the vicinity of a coal-fired power station in Hadera, Israel. Goren and colleagues (1995) aimed to detect spatial or temporal changes in the health status of a population residing within a 10km radius of a coal-fired power station. The survey results showed that among adults, a seasonal trend of more frequent use of outpatient clinics due to respiratory complaints was observed. The major explanatory factor for use of outpatient clinics was lower ambient temperatures; the other was a flu epidemic. Interestingly, a significant increase in the use of outpatient clinics was observed for certain years, while in other years there was a decrease. The investigators found that the follow-up failed to demonstrate any deterioration in lung function or differences in the severity of respiratory complaints as compared with a similar population residing in a rural, clean area with no major environmental polluting source. Air pollution levels measured around the coal-fired power station in Hadera were low and may explain these results.

D. COAL COMBUSTING POWER stations – Children, infants, and fetal outcomes

Respiratory disease

A further Israeli study by Goren and Hellmann (1997) in the vicinity of the same coal combustion assessed signs and symptoms of respiratory disorders in schoolchildren in three communities with different expected levels of air pollution. Follow up comparisons were undertaken every three years. A significant increase in the prevalence of asthma was observed among the data from the fifth grade children in all three communities. At the same time a significant rise in the prevalence of wheezing accompanied by shortness of breath was observed. A similar trend could not be found for the prevalence of bronchitis and other respiratory conditions. As expected, pulmonary function tests (PFTs) of children suffering from asthma or from wheeze accompanied by shortness of breath were worse than those of healthy children. Changes in the prevalence of possible contributing factors could not explain the significant rise in asthma. The authors concluded that this effect and related respiratory conditions coupled with reduced PFTs suggest a true increase in morbidity and not a reporting bias. However, the increased prevalence of asthma could be observed in all the communities studied thus not appearing to be connected with the operation of the power plant.

A subsequent Israeli study assessed whether fine particles were a risk to lung function in a group of school children (n = 285) with asthma living near two power stations in the region (Peled et al, 2005). This nested cohort study compared three communities which each had a fine particle monitoring station. After controlling for confounders known to affect lung function, air pollution by ultra-fine particles (PM_{10} and $PM_{2.5}$) were found to be significantly associated with decreased lung function. It is noteworthy that this adverse respiratory effect was observed at levels below the Israeli air quality standards.

In yet another Israeli study, researchers analysed the association between children's lung function development and their long-term exposure to air pollution using GIS tools (Dubnov et al, 2007). Data collected three years apart on 1,492 school children living in the vicinity of a coal-fired power station, indicated that PFT results deteriorated as estimated individual levels of air pollution increased. Other factors were evaluated for possible effects on lung function but none were found to be statistically significant. The authors concluded that air pollution from the coal-fired power station, although not exceeding local pollution standards, had a negative effect on children's lung function development. A more recent analysis of these children evaluated the effects of exposure to air pollution on lung function, characterised by health status (Yogev-Baggio et al, 2010). The children were subdivided into three health status groups: i) healthy children, ii) children experiencing chest symptoms, and iii) children with asthma or spastic bronchitis. After controlling for socio-demographic characteristics and living conditions, exposure to air pollution appeared to have had the greatest effect on children with chest symptoms.

A study from Maemoh, northern Thailand, evaluated the association of short-term exposure to increased ambient sulphur dioxide (SO_2) and daily lung function changes among children aged 6-14 years with and without asthma who resided near a coal-fired power station (Aekplakorn et al, 2003). The results demonstrated an adverse effect of short-term exposure to air pollution on lung function in children with symptoms of asthma. It was concluded that declines in lung function among asthmatic children are associated with increases in particulate air pollution, rather than with increases in SO_2. The authors noted that the concentrations of pollutants were relatively low, possibly due to recent measures to mitigate SO_2 emissions, and may have limited the study outcomes. The application of these results to the Hunter Region may be limited as this is a lignite coal-fired power station.

Undertaken a little over 20 years ago, a study in Lake Munmorah, a NSW coastal town between two coal-fired power stations, investigated respiratory problems in primary school children (Henry et al, 1991a). A prevalence survey and longitudinal follow-up study were conducted one year apart. Both studies found that the prevalence of 'ever wheezed', 'current wheezing', 'breathlessness', 'wheezing with exercise', diagnosed asthma, and use of drugs for asthma were all approximately double compared with the NSW control town of Nelson Bay – a coastal non mining area. Airway test results were impaired in the study group in the first survey but not statistically significant at follow-up. The authors concluded that the impaired respiratory results were due to an environmental cause.

In a further study to assess the effect of living in Lake Munmorah on children with asthma, 94 children with asthma were studied for one year and compared with a similar group living in Nelson Bay (Henry et al, 1991b). Air quality measurements of SO_2 and nitrogen oxides were well within Australian recommended limits in both areas although they were several times higher at Lake Munmorah where marked weekly fluctuations were observed in the prevalence of cough, wheezing, and breathlessness in the study group compared with the control group in Nelson Bay. However, these differences were not statistically significant. The authors concluded that air quality measurements were not associated with the occurrence of respiratory symptoms.

Halliday and colleagues (1993) undertook a third study in this series. This was a cross-sectional survey of school children (aged 5 to 12 years) from the same exposed group as previous studies but with a different socioeconomically matched control population (Dungog, Hunter Valley). The authors compared respiratory measurements and asthma symptoms between the two groups. Baseline lung function was lower and reported symptoms of asthma were higher in children from the power station town, but airway test results were similar. These results confirm the increased presence of reported symptomatic illness in the town near the power stations.

Toxins – arsenic, chromium, and oxidative stress

Oxidative DNA stress is believed to play an important role in certain diseases and conditions including cancer and premature ageing.

A cross-sectional study in Taiwan comparing school children (aged 10-12 years) from three different elementary schools was undertaken to investigate possible associations between proximity to a power station and urinary levels of arsenic, chromium, and nickel and the level of DNA oxidative stress (Wong et al, 2005). Of the selected schools, one (exposed) was adjacent to a power station, with eight coal-fired generation units. The remaining schools (controls) were located in suburban communities, approximately 8km and 18km north-eastern and upwind from the power station. The results indicated that children in the exposed elementary school had higher urinary 8-hydroxy-2´-deoxyguanosine (8-OHdG) levels than did those at the control schools - 8-OHdG being a biomarker of oxidative stress. The authors further reported that children with higher urinary arsenic or chromium had greater urinary 8-OHdG. There was also a significant trend between children with high urinary arsenic and chromium and children with high urinary 8-OHdG levels, followed by those with low arsenic/high chromium, and low arsenic/low chromium. No obvious relationship between the levels of urinary nickel and 8-OHdG was found. From these results the authors concluded that environmental carcinogenic metal exposure to chromium and arsenic may play an important role in oxidative deoxyribonucleic acid damage in children.

Infant and fetal outcomes

Mohorovic (2004) studied pregnant women residing in the vicinity of a coal power station in the Croatian town of Labin. The power station is the single major air polluter in the area and the coal burnt there has a very high sulphur content (9-11%). This retrospective epidemiological study investigated what was the most critical gestation period for adverse effects of coal combustion products in relation to preterm delivery (< 37 weeks) and low birth weight (< 2.5 kg). The analysis indicated that a greater and longer exposure to SO_2 emissions during the initial two months of pregnancy resulted in a significantly shorter gestation and lower birth weight. The authors concluded that these results confirm the role of inhaled environmental toxins in the early development of the human embryo and in adverse pregnancy course caused by permanent oxidative stress, misbalanced production of reactive oxygen, nitrogen and sulphur species as well as other unfavourable metabolic processes on early embryo development and growth, resulting in growth-arrested cells.

A more recent epidemiologic study by Mohorovic and colleagues (2010) investigated the relationship between exposure to products of coal combustion and complications in pregnancy. Records of miscarriages, premature births and stillbirths were compared across two periods:

- the control period when the plant was closed for almost 7 months
- the exposure period when the plant was operating.

Analysis of data on 260 pregnant women found that the frequency of miscarriages and stillbirths were significantly lower in the control period compared with the exposure period. Additionally, stillbirths and a blood biomarker (methemoglobin) for adverse environmental effects on the mother and fetus, recorded over the exposure period, were significantly higher than in the control period.

In another study, researchers from Columbia University examined the relationship between prenatal polycyclic aromatic hydrocarbon (PAH) exposure and fetal and child growth and development in Tongliang, China (Tang et al, 2006). A seasonally operated coal-fired power station is the major pollution source in the vicinity. PAHs are an important class of toxic pollutants released by fossil fuel combustion. Polycyclic aromatic hydrocarbon-deoxyribonucleic acid (PAH-DNA) adducts provide a measure for calculating PAH exposure, and have been associated with increased risk of cancer and adverse birth outcomes. Results from a group of non-smoking women and their newborn infants indicated high PAH-DNA adduct levels (above the median detectable level) which were associated with decreased birth head circumference, birth length, reduced children's weight and height at 18, 24, and 30 months of age. The findings indicate that PAHs from coal burning power stations are harmful to the developing fetus and child.

A two year follow-up of the same subjects evaluated the association between levels of PAH-DNA adducts, lead, and mercury (Tang et al, 2008). The data from the mother-child pairs found that decrements in one or more developmental areas (motor, adaptive, language, and social) were significantly associated with cord blood levels of PAH-DNA adducts and lead, but not mercury. Increased adduct levels were also associated with a significantly decreased motor area developmental quotient (DQ) and average DQ, after adjusting for variables. The DQs the authors assessed were motor, adaptive, language and social areas. From the results, the authors concluded that in utero exposure to PAHs from the coal-fired power station adversely affected the development of children living in Tongliang.

The permanent closure of the Tongliang power station (China) provided an opportunity to evaluate the effect of the closure on neuro-behavioral development in women and their newborns (Perera et al, 2008). Two identical prospective cohort studies (pre- and post-plant shutdown) were compared. Significant associations between elevated PAH-DNA adducts and decreased motor area DQ and average DQ previously seen in the pre-plant shutdown study were not observed in the post-plant shutdown cohort. However, the direction of the relationship did not change. The findings suggest that neurobehavioural development in Tongliang children benefited from the elimination of PAH exposure from the coal burning plant.

Author's comments

Studies from a number of countries show clear associations between coal mining and combustion activity and health harms from major impacts, up to and including excess deaths, to minor respiratory complaints such as coughs and wheezing. However, it should be noted that there are inherent difficulties in designing population and community studies that can unequivocally attribute and precisely quantify associations as it is often not possible to control the many factors and confounders that impact on the research subjects. The main limitation to the evidence cited in this section is the difficulty in accurately, precisely and reliably measuring exposure in studies involving air quality, although these methodologies are improving rapidly. It should also be noted that mining practices and regulatory standards vary across countries and may account for different effects. For example, mountain top removal for mining purposes as carried out in parts of the US may cause additional negative health effects and is not used in Australia to our knowledge.

Conversely, there are a number of factors which may result in underestimation and /or under reporting of coal related health harms for local communities. There is a lack of long term prospective studies which may mean that causal associations between mining activity and diseases with a long time lag, such as cancers, may be underestimated. Some of the studies we reviewed were conducted up to 20 years ago, including the few Australian studies, and it could be assumed that the huge expansion in coal mining over that period may have amplified any health impacts. Further, we excluded studies of air pollution from our reviews if the study did not specify coal mining or combustion as the pollution source - although it may well have been a contributor in some studies.

Several international studies highlight the presence of harmful airborne pollutants and toxins associated with coal extraction and combustion but do not link these with health outcomes and were therefore not included in our evidence review. However, it is reasonable to assume that these pollutants and toxicants had adverse health effects on local residents. For example, a study conducted in the highly polluted area of Silesia in Poland in the 1990's showed high levels of PAHs in environmentally exposed individuals compared with others in Western Europe, and compared to non-exposed individuals in the same region (Øvrebø, 1995). Another study in the highly polluted area of Lodz in Poland, which is associated with three coal-fired power stations, found a 20% increase in gamma radiation producing nucleotides attributable to power station emissions (Bem et al, 2002). Several studies from India, the world's third largest coal producer, have looked at dust production from open-cast mining. A study of one large open-cast coal mining project found that the total dust emitted was estimated to be 9368kg/day. The various sources of emissions including fugitive emissions; dust from vehicular traffic on haul roads; and wind erosion from stockpiles were found to be significant sources of dust (Ghose & Majee, 2007). The authors conducted a further study collecting worksite data and ambient air quality monitoring for a year at five locations. The authors found high levels of PM_{10}, total respirable matter and benzene soluble matter (benzene is a known human carcinogen). A previous study in India also found high levels of dust associated with coal washeries that exceeded local standards; 50% of soluble particulate matter was less than $PM_{10,}$ and high levels of benzene soluble matter were found including ambient air measurements (Ghose & Banerjee, 1995).

A review of air pollution and cardiopulmonary disease in Australia published in 2005 (Howie et al, 2005) concluded that the weight of Australian studies reviewed (n=13) indicated that air pollutants (eg PM_{10}, SO_2 and nitrogen oxide) were associated with an increase in cardiovascular and respiratory mortality and hospital admissions, consistent with the international evidence, and that these effects occur at even lower levels than the current national standards. The authors also noted significant gaps in the literature such as defining exposure thresholds, determining population exposures distributions, disentangling the effect of one air pollutant from another and the interactive effects of pollutants and other environmental factors. New associations with air pollution are also emerging; studies are finding an association between diabetes and particulate matter in the US (Pearson et al, 2010). The International Collaboration on Air Pollution and Pregnancy Outcomes was formed in 2007 to further understand relationships between air pollution and adverse birth outcomes, following evidence from numerous studies showing adverse outcomes, including low birth weight, preterm delivery and infant mortality (Woodruff et al, 2010).

The American Heart Association's 2010 Scientific Statement on Particulate Matter Air Pollution and Cardiovascular Disease (Brook et al, 2004) includes advice that exposure to $PM_{2.5}$ or less over a few hours to weeks can trigger CVD deaths as well as non-fatal events. Longer term exposure increases the risk of CVD mortality in more exposed individuals and reductions in $PM_{2.5}$ lead to reductions in CVD mortality within a few years. Exposure to $PM_{2.5}$ is deemed a modifiable factor that contributes to CVD morbidity and mortality. CVD is listed as the leading cause of death in Australia.

The limited amount of evidence available for Australia is disappointing but, in the absence of current local studies it is reasonable to extrapolate the international evidence to Australia – particularly where that evidence comes from comparable countries.

Research Question 2

Are there clusters of these diseases or other health problems in the Hunter Region of NSW?

Introduction

Australian data on the health impacts of coal mining are very limited and we found no Australian studies reporting specific disease clusters or 'hot-spots' in communities living near coal mines. Notwithstanding this, there are numerous anecdotal reports of perceived disease clusters in the Hunter Region including for cancer and type 1 diabetes, and concomitant high levels of concern within local communities living near mining sites.

In 2010, in response to community concerns, the NSW Chief Health Officer convened an Expert Advisory Panel to look into the issue of air quality in the Hunter Region. This panel produced the report cited below as the "NSW Health Report". At the time of writing our report on the *The Health and Social Harms of Coal Mining in Local Communities*, we believe that the NSW Ministry of Health (formerly known as the NSW Department of Health) is in the advanced stages of planning a study of air quality in the Hunter Region. We understand that this study will draw on information from 14 air monitoring stations, with two of these stations monitoring $PM_{2.5}$ particles ie those that pose the greatest health risks.

While we await the NSW Ministry of Health study, it is reasonable to assume that the evidence from the US and other developed countries would be applicable in the Australian context. In the interim, to determine the status of disease clusters in the Hunter Region we reviewed the publicly available data on the health of people living in the (former) Hunter-new England Area Health Service (HNEAHS) which covers all but 9% of the population of the Hunter Region, and relevant sections of the BEACH general practice data.

The information summarised below and described in detail on the following pages is contained in two reports which analyse and present routinely collected health monitoring data ie:

- A report published in 2010 by the Population Health Division, NSW Department of Health entitled ***"Respiratory and cardiovascular diseases and cancer among residents in the Hunter New England Area Health Service"*** (NSW Health 2010a). Available at:
  http://www.health.nsw.gov.au/pubs/2010/pdf/HNE_Respi_Cardio_Disease.pdf

- A report providing results of data analysis from the Bettering the Evaluation and Care of Health (BEACH) Program (NSW Health 2010b) entitled ***"Analysis of BEACH general practitioner encounter data to examine the potential health effects of the mining industry and other exposures in Singleton, Muswellbrook and Denman"*.** Available at:
  http://www.health.nsw.gov.au/pubs/2010/beach_report.html.

Summary of Evidence for Research Question 2

There is no direct research evidence available on coal related disease clusters in the Hunter Region and the evidence from analyses of routine monitoring data shows variable and inconclusive results.

For example, comparisons of the two geographical areas with extensive open-cut mining and power generation activities showed that the death rate from all causes was significantly higher in the Lower Hunter cluster but significantly lower in the Upper Hunter cluster than the death rate for NSW as a whole. Further, the two geographical areas reporting higher (but not statistically significantly higher) rates were not particularly exposed to extensive open-cut coal mining or power generation. Lung cancer incidence was not significantly different to the whole of NSW and although some other types of cancer were more commonly reported these were not cancers usually associated with coal mining or coal combustion.

Nonetheless, the NSW Health Report on residents of the HNEAS who may be exposed to air pollution from mining activity concluded that:

“Compared with the rest of NSW, one or both of Upper Hunter and Lower Hunter, the geographical regions of HNEAHS most affected by open-cut coal mining and power generation plants, have higher rates of:

- Emergency department attendance for asthma and respiratory disease (but also for all other conditions, which may indicate a general tendency to greater use of emergency departments in these regions)
- Hospital admission for all respiratory conditions together and for asthma (Upper Hunter only)
- Hospital admission for cardiovascular disease
- Death from all causes and cardiovascular disease (Lower Hunter only).”

The BEACH Report found that the rates of illness in people presenting to general practitioners (GPs) in the Upper Hunter were similar to comparable areas of NSW and did not find any significantly higher rates of any problems managed, or medications prescribed or supplied in the Upper Hunter Region compared with the rest of non-metropolitan NSW. It concluded that is reasonable to assume that the minor differences in the GP data for Singleton, Muswellbrook and Denman are likely due to chance rather than actual differences in disease rates, but it conceded that asthma may be a more important issue in the Upper Hunter.

The BEACH Report recommended that further study of the health effects of the mining industry and other exposures in the Hunter Region should focus particularly on asthma and other respiratory diseases.

Details of the Evidence for Research Question 2

For administrative purposes NSW was, until recently, geographically divided into Area Health Services (AHSs). These are now known as Local Health Districts but there is little difference between the boundaries of the Districts and the former AHSs. As Table 2 shows, the HNEAHS covered 25 LGAs grouped into eight clusters. Most of these LGAs are included in the Hunter Region and only 9% of the population covered by the HNEAHS falls outside the Hunter Region.

Table 3 HNEAHS estimated total residential population by cluster and LGAs

HNEAHS cluster	LGA	Population
Greater Newcastle	Lake Macquarie	195 479
	Newcastle	153 171
	Port Stephens	67 144
	Subtotal	**415 794**
Lower Hunter	Cessnock	49 751
	Dungog	8 539
	Maitland	69 878
	Singleton	23 747
	Subtotal	**151 913**
Lower Mid North Coast	Gloucester	4 995
	Greater Lakes	35 986
	Greater Taree	47 866
	Subtotal	**88 847**
McIntyre	Inverell	16 169
	Gwydir	5 421
	Subtotal	**21 591**
Mehi	Moree Plain	14 427
	Narrabri	13 454
	Subtotal	**27 881**
Peel	Gunnedah	11 840
	Tamworth	57 066
	Walcha	3 291
	Subtotal	**72 197**
Tablelands	Armidale Dumaresq	24 538
	Guyra	4 404
	Tenterfield	6 812
	Uralla	6 008
	Glen Innes Severn	9 065
	Subtotal	**50 827**
Upper Hunter	Muswellbrook	16 167
	Upper Hunter Shire	13 524
	Liverpool Plains	7 825
	Subtotal	**37 516**
HNEAHS combined	**TOTAL**	**866 566**

Source: NSW Health, 2010a. Respiratory and cardiovascular diseases and cancer among residents in the Hunter New England Area Health Service.

OVERVIEW OF FINDINGS FROM THE NSW HEALTH REPORT (2010A)

According to the NSW Department of Primary Industry (2009) there are six coal-fired power stations in the Hunter-Newcastle Coalfield Region and Table 4 indicates the location and number of coal mines in the HNEAHS.

Table 4: Number of operating coal mines in the Hunter New England Area Health Service, April 2010

LGA	**Coal mines**		
	Open-cut	**Underground**	**Combined (open-cut & u/ground)**
Singleton	11	2	4
Muswellbrook	5	-	1*
Cessnock	1	1	1
Lake Macquarie	1	5	-
Gloucester	1	-	-
Great Lakes	1	-	-
Gunnedah	3	-	-
Liverpool Plains	1	-	-
Narrabri	2	1	-
TOTAL	**26**	**9**	**6**

*The combined open-cut and underground coal mine in the Muswellbrook LGA also falls across into boundary of Singleton LGA. Not included in data set for Singleton LGA.

Source: Adapted from NSW Health, 2010a. Respiratory and cardiovascular diseases and cancer among residents in the Hunter New England Area Health Service.

The NSW Health Report (2010a) focused on diseases and causes of death previously associated in the international health literature with exposure to air pollutants, and on certain diseases of concern to communities in the HNEAHS. It presents emergency department data by postcode; hospital separations rates by LGA; and mortality and self-reported health data by HNEAHS cluster. The purpose of the Report was to i) assess the health of the residents of the HNEAHS, ii) compare the health of HNEAHS residents with the health of residents of other parts of NSW, and iii) examine variations in health within HNEAHS in relation to the distribution of coal mining and coal-fired power generation in the area. The main health conditions and health reviewed in the NSW Health Report are described below under the following headings:

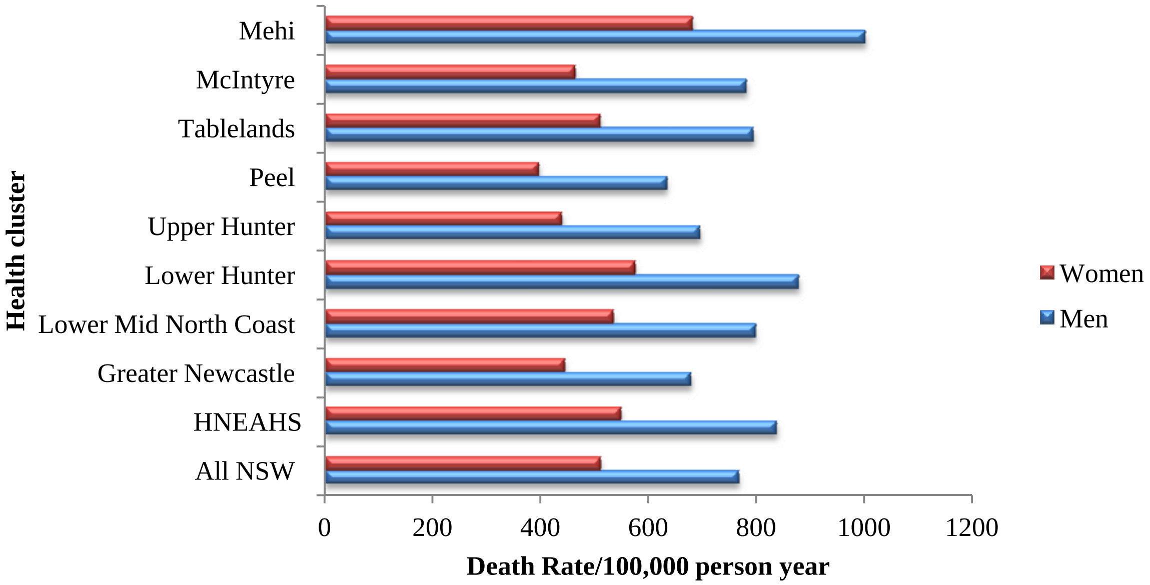
- Mortality (death)
- Cancer
- Emergency department presentations for respiratory illness and asthma
- Hospital separations from respiratory diseases (including asthma and cardiovascular diseases)
- Self-reported data on overall health, asthma and smoking.

Mortality (death)

All-cause mortality

The death rate from all causes is significantly higher in the Lower Hunter cluster (Rate/100,000 person year 703.87) but significantly lower in the Upper Hunter cluster (Rate/100,000 person year 555.96) (the two clusters with extensive open-cut mining and power generation activities) than the death rate for NSW as a whole (Rate/100,000 person year 624.01). Within HNEAHS, the death rate from all causes is highest in the Mehi cluster (Rate/100,000 person year 832.14). Mehi has a higher proportion of Aboriginal residents.

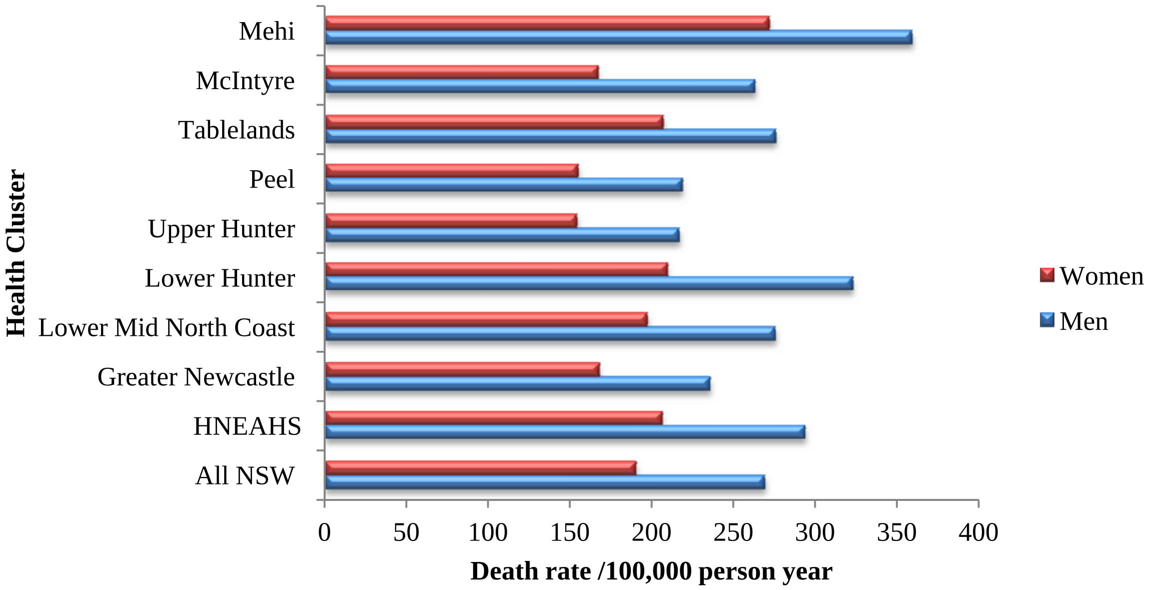
Figure 2: All cause mortality in males and females by HNEAHS cluster, HNEAHS and NSW



Cardiovascular disease mortality

For the period 2002-07, the CVD death rate was significantly higher for HNEAHS (Rate/100,000 person year 245.83) than for NSW (Rate/100,000 person year 225.06). The Lower Hunter cluster had a significantly higher rate of CVD deaths (Rate/100,000 person year 256.51), while the Upper Hunter cluster had a significantly lower rate (Rate/100,000 person year 184.84) of CVD deaths than NSW as a whole. Two LGAs (Gunnedah and Narrabari) had a rate more than 50% higher than the state average.

Figure 3: Cardiovascular diseases mortality in males and females by HNEAHS cluster, HNEAHS and NSW

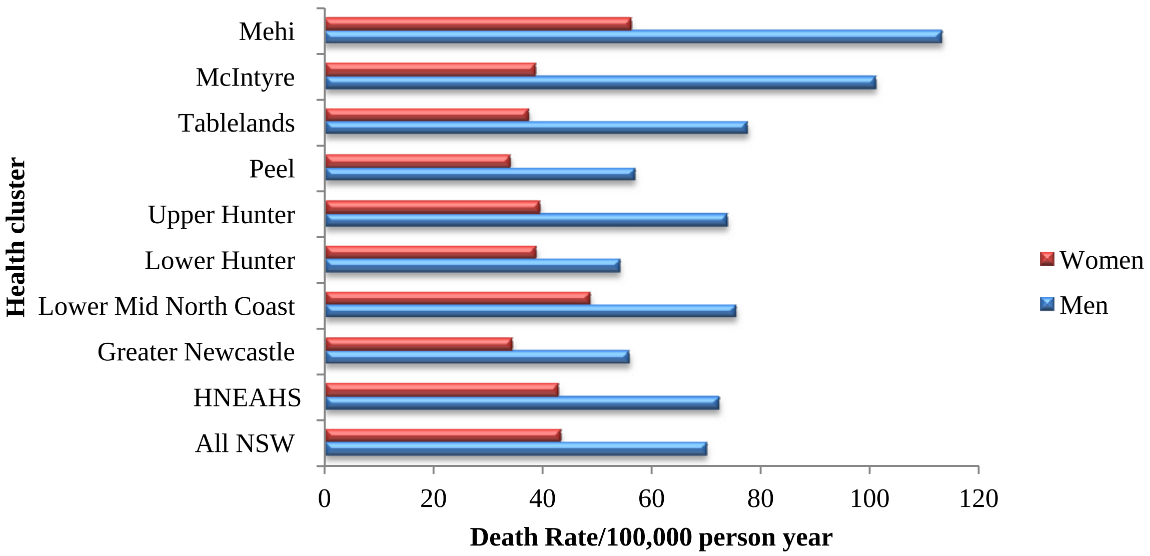


All respiratory disease mortality

The death rate from all respiratory disease for HNEAHS (Rate/100,000 person year 54.67) was not significantly different to NSW as a whole (Rate/100,000 person year 53.98). The clusters with extensive open-cut mining and power generation activities, the Upper and Lower Hunter clusters, have rates of death from respiratory disease that are similar to but lower than the HNEAHS as a whole. The rates were:

- Upper Hunter: Rate/100,000 person year 54.26
- Lower Hunter: Rate/100,000 person year 45.10
- HNEAHS: Rate/100,000 person year 54.67

Figure 4: All respiratory disease mortality in males and females by HNEAHS cluster, HNEAHS and NSW



Cancer

Cancer incidence and mortality data for the period 2003-07 indicated that HNEAHS had significantly higher incidence rates for all cancer (Rate/100,000 person year 469.3 vs 448.9) and a higher rate of death from cancer (Rate/100,000 person year 192.8 vs 178.3) than NSW overall. However, the higher rates which contributed to this effect were for colorectal and prostate cancers, and melanoma which are not thought to be associated with air pollution.

Lung Cancer

Lung cancer incidence for HNEAHS for all persons, (Rate/100,000 person year 39.7) was similar to the rate for NSW (Rate/100,000 person year 40.3), and was not significantly higher in any of the areas with extensive open-cut mining and power generation activities. Within HNEAHS, the lung cancer incidence rate for all people in the Mehi cluster (Rate/100,000 person year 60.2) was higher than for other clusters, consistent with the higher (but not statistically significantly higher) smoking rates reported for the Mehi cluster.

The incidence of lung cancer in men in the Upper Hunter (Rate/100,000 person year 69) was also higher than that for men in NSW (Rate/100,000 person year 54.6). This effect was not statistically significant, nor was it true for men in Lower Hunter (Rate/100,000 person year 55.4), the other cluster with extensive open-cut mining activities, or for women in either of these clusters (Figure 5).

Lung cancer mortality rates for all persons for HNEAHS (Rate/100,000 person year 34.9) were also similar to the rate for NSW (Rate/100,000 person year 33.5), and were not significantly higher in any of the areas with extensive open-cut mining and power generation activities (Figure 6).

Figure 5: Lung cancer – new cases in males and females by HNEAHS cluster, HNEAHS and NSW.

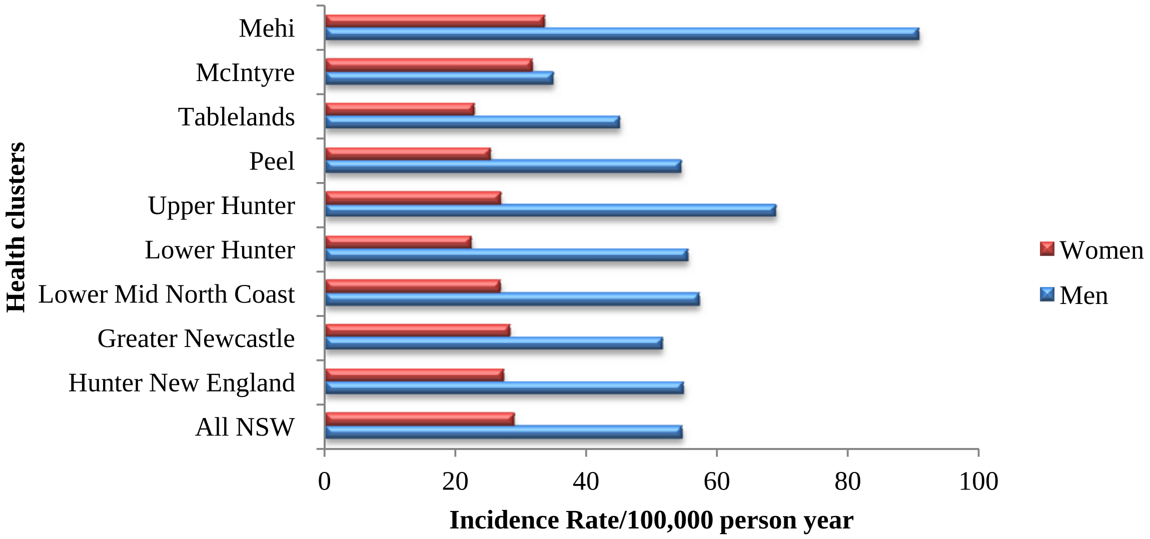
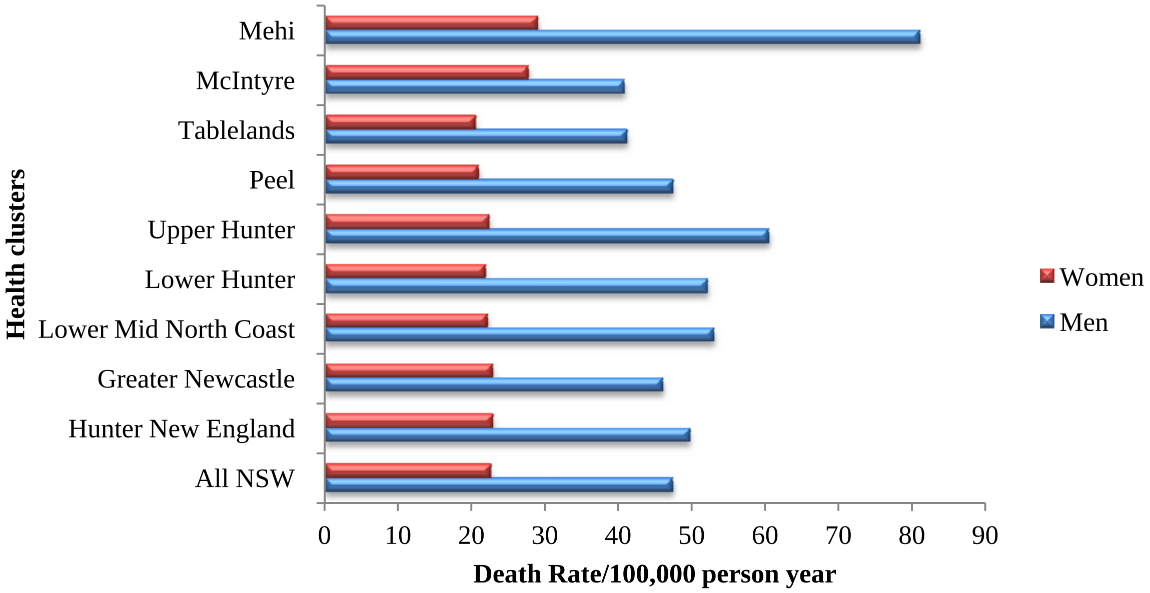


Figure 6: Lung cancer – mortality in males and fremales by HNEAHS cluster, HNEAHS and NSW



Brain cancer cluster

The NSW Health Report (2010a) cited an investigation of five cases of brain cancer reported occurring within two streets in Singleton. These cases were diagnosed between 1979-2008. A cluster investigation was undertaken and concluded that the geographical location of these brain tumour cases was most likely to be a chance occurrence. A report on this investigation is available at: http://www0.health.nsw.gov.au/resources/news/singleton_cancer_pdf.asp

Emergency department presentations for respiratory illness and asthma

Data for the total number of residents in HNEAHS who presented to emergency departments and who were assigned a diagnosis of any respiratory condition (including asthma) were obtained from the NSW Emergency Department Data Collection for the period 2007-09 inclusive and showed that:

- Rates of presentation for all respiratory illnesses in Muswellbrook and Singleton postcodes ranked below those of Tamworth, Gunnedah and Cessnock in all age groups
- The Muswellbrook area had high rates for emergency department presentation for asthma, but not the highest in HNEAHS
- Singleton ranked highly for rates of emergency department presentations for asthma in people aged 15-64 years
- Muswellbrook and Singleton were equally highly ranked for rates of other emergency department presentations for conditions unrelated to air pollution.

Hospital separations for respiratory diseases, asthma and cardiovascular disease

NSW Admitted Patients Data Collection and population estimates from the NSW Centre for Epidemiology and Research highlighted the following:

- Singleton and Muswellbrook LGAs had significantly higher rates of hospital separations for CVD than all of HNEAHS or NSW
- Other LGAs in HNEAHS that do not have open-cut coal mines or power generating plants also had higher rates of CVD hospital separations
- Muswellbrook had a significantly higher separation rate for respiratory disease, whereas Singleton had a lower, but not significant, separation rate compared with NSW
- Asthma separation rates also showed a mixed pattern, with significantly higher rates in Muswellbrook and Narrabri, but lower rates in Cessnock and Singleton, compared with all of HNEAHS and NSW.

Self-reported data on overall health, asthma and smoking

Overall health

No difference in overall self-rated health was found between residents of HNEAHS and NSW, or between residents in any of the areas within HNEAHS clusters.

Asthma

- There was no statistically significant difference in self-reported asthma in adults in the HNEAHS compared with the rest of NSW. The only areas reporting higher asthma prevalence were Mehi and Peel. Neither of these regions is exposed to extensive open-cut coal mining or power generation industries

- The rate of parent/carer-reported asthma for children aged 15 years or younger was similar in all regions of the HNEAHS and was significantly higher than for the rest of NSW. The higher asthma rates were reported in those LGAs that contain the greatest concentration of open-cut coal mines and power stations, and also in LGAs containing few or no coal mining.

OVERVIEW OF THE BEACH PROGRAM: GENERAL PRACTICE DATA FOR THE THE UPPER HUNTER

To determine potential community health effects at general practice level, the BEACH Program collected data from 1000 GPs randomly selected across Australia. Each GP provided data on the problems managed and treatment provided for 100 consecutive patients. In 2010, in response to health concerns raised by members of the Singleton Shire Healthy Environment Group, sub-analysis of the data from the BEACH program was conducted to examine the potential health effects of the mining industry and exposure in Singleton, Muswellbrook and Denman postcodes. This sub-analysis aimed at examining if there was a difference in the type of health problems managed by GPs for residents of Singleton, Muswellbrook and Denman postcodes combined (in this analysis it is called Hunter Region postcodes) compared with residents of all other non-metropolitan NSW postcodes.

For the Hunter Region, BEACH encounter data were provided by 18 different GPs representing seven general practices. Of relevance to the context of this report it provided the following information on the Hunter Region:

- Over the period 1998-2010, the BEACH Program data showed that there were no significantly higher rates of any problems managed or medications prescribed or supplied in the Hunter Region than in the rest of non-metropolitan NSW

- Rates per 100 GP encounters for management of COPD and asthma combined (4.4 vs 3.7), sinusitis (2.1 vs 1.3), tonsillitis (1.6 vs 0.9), and acute otitis media (1.4 vs 1.1) were higher in the Hunter Region postcodes than in the rest of non-metropolitan NSW but these increases were not statistically significant.

Higher rates (per 100 problems) of bronchodilators (2.1 vs 1.8) and asthma preventive medications (1.9 vs 1.4) were prescribed for residents in the Hunter Region postcodes compared with other non-metropolitan NSW postcodes but these differences were also not statistically significant.

Author’s comments

There have been no specifically designed studies to determine the cause of disease patterns in the Hunter Region. The available data to address this question are taken from reliable, routine health monitoring sources but are variable and difficult to interpret, and contain some unexplained results.

There are many potentially confounding variables and inherent methodological difficulties in designing studies that can accurately measure exposure to pollution and toxins and contaminants from mining and explain observed associations. Consequently, the lack of research evidence does not necessarily mean there is no problem. Rather, it may simply mean that a study capable of determining the extent of the problem has not yet been undertaken. Therefore, we note that:

a) there is an urgent need to determine the nature and extent of health impacts on people living in communities close to coal mines and coal-fired power stations in the Hunter Region

b) the NSW Ministry of Health is believed to be planning a study of the health effects of air pollution in the Hunter Region.

Research Question 3

Is social injustice associated with coal mining in local communities?

"Among the most basic and commonly understood meanings of justice is fairness or reasonableness, especially in the way people are treated or decisions are made. Justice stresses fair disbursement of common advantages and the sharing of common burdens. But it does more than that by demanding equal respect for all members of the community" Gostin, 2007.

Introduction

There are multiple definitions of social injustice, with notions of distributive and participatory injustice commonly occurring. Therefore, for the purposes of this Report, we defined social injustice as:

'the unequal or unfair social distribution of rewards, burdens, and opportunities for optimising life chances and outcomes'.

Our literature searches found relatively few peer reviewed journal articles from the international literature that address social injustice in people living in communities near coal mines or coal fried power stations. We identified six peer reviewed journal articles directly addressing social injustice associated with coal mining. These covered a wide geographical range ie the UK, US, Russia and Australia (QLD). While there were some limitations to the studies we reviewed, the central theme of social distress and impact on local communities of both real and perceived environmental degradation is consistent with the Australian literature cited under Research Question 4 of this Report and included:

- Environmental damage and perceptions of damage and related health impacts
- Water quality and changes to means of local livelihood
- Social and economic impacts.

These categories were generated from the literature rather than being pre-determined by the authors of this Report.

Summary of Key Findings for Research Question 3

Social injustices associated with mining in local communities

Aside from the six studies from the Hunter Region, which are detailed under Research Question 4 (page 38), we found few studies focussing on social injustice in relation to mining in the broader international literature. However, despite some limitations, the six journal articles we reviewed from the US, the UK, Russia and QLD detailed a range of social injustices including:

Environmental damage and perceptions of damage and health impacts

- Slurry spills
- Lack of community awareness of damage
- Distress resulting from concerns and uncertainties about direct health impacts of mining-related pollution as well as associated impacts.

Water quality and human occupations (activities)

Human occupation in this context refers to a range of human activity from everyday house-hold activities to activities associated with income earning, and social and recreational activity.

- Three types of occupational injustice are noted in the literature: i) occupational deprivation, ii) occupational imbalance, iii) occupational alienation
- Water pollution resulting from coal mining activity rendering local water sources unsafe to drink, unsafe for growing agricultural produce, and unsafe for recreational activities such as swimming or fishing
- More than one study notes the adverse smell of clothes washed in water polluted from mining activity and the additional cost and inconvenience of being forced to buy bottled water due to unsafe drinking water.

Social and economic costs

- Disproportionate damage imposed on local communities versus the minor penalties imposed on mining companies to compensate for the damage
- Government (society) bearing the cost of regeneration programs to redress damage caused by mining activity
- Inability of the community to capture economic benefits
- Social changes inhibiting the generation of alternative means of economic capital to survive mining downturns
- Socio-demographic changes resulting in shortages of skilled labour in other industries; reduced access to and affordability of accommodation; increased road traffic and fatigue-related road accidents; increased pressure on local (volunteer) emergency services; and increases in criminal and other anti-social behaviours.

Detailed Description of the Evidence for Research Question 3

Environmental damage and perception of damage and related health impacts

A study was undertaken in the Letcher County of Kentucky, US, to explore water pollution associated with coal mining activities (Blakeney & Marshall, 2009). The authors noted numerous polluting events which led the US Environmental Protection Agency to place restrictions on human contact with water in the Letcher Country area. For example, there is a 'no bodily contact' advisory for an 86 mile stretch of river. A further 633 miles of the river basin is considered unsafe for any human use. A number of accidents have occurred with coal slurry spills, including loss of life and homes. In the year 2000 one such spill released 300 million gallons of slurry, causing the contamination of 27,000 homes and the local water supply. The outcome of the spill was a $5,500(USD) fine for the party responsible for the damage. The disproportionate outcome of the spill, with large scale environmental damage resulting in an insignificant fine for the perpetrator, is a clear indication of environmental injustice.

A qualitative study exploring the health and environmental concerns of parents living close to open-cut mines in the UK (Moffatt & Pless-Mulloli, 2003) was undertaken in tandem with an epidemiological study conducted by Pless-Mulloli and coleagues (2000) into the health effects of open-cut mining. In the qualitative study, the researchers carried out in-depth semi-structured interviews with 31 parents selected from four of the five sites of the epidemiological study. The authors focussed on non-activist participants since their claims are unknown and unexplored. While the aim of the study was to determine the usefulness of undertaking concurrent qualitative and quantitative studies, the results included findings relevant to the question of social injustice.

For example, the main theme that emerged from the interviews centred on environmental concerns and all participants felt that there was some impact in their area from mining activity. Other key themes were the social, economic, and health impacts of open-cut mining. A unifying feature between the sites was participants' affinity with the landscape and surrounding countryside, and the disruption characterised by losing "reliability of *places"* (Moffatt & Pless-Mulloli, 2003). Concern over social and economic impacts varied depending on perceived economic advantages and any contributions to local wellbeing such as funding for community projects. Health impact themes related to uncertainty and anticipation, and the most common concern was about asthma caused by open-cut mining. Health and environmental risk perceptions did not vary between parents with or without children with asthma. Participants expressed that their concern of increased asthma had been ignored by relevant authorities in the planning stages of mines, thus expressing the well documented theme of mistrust of official sources of information. However, consistent with the finding that there has been no increase in the prevalence of asthma from the epidemiological study, parents expressed uncertainty and speculation on increasing asthma rates generally and only one parent reported that their child had been adversely affected. Concerns about the direct impact of open-cut mines were lower in priority than associated concerns such as traffic accidents and danger from the increased number of strangers in the community.

There were a number of limitations to this study including a low response rate. However, the authors noted that the concurrence of parents' views and the epidemiological findings (no increase in asthma but more dust and more GP visits) is unusual. They also note that uncertainty about health effects is sometimes used to assist the mining industry in denying the effects of open-cut mines, but it can also be used by local communities to help oppose applications for mines due to the precautionary principle.

A study in northeast Russia from 1998-2001 compared residents' perceptions of pollution with quantitative assessment of pollutants from the Tundra Degradation in the Russian Arctic (TUNDRA) project and was sponsored by the European Commission (Walker et al, 2006). Participants were selected from among town dwellers and six rural villages in two separate socio-geographical areas:

- a coal mining area including the town of Vorkuta
- the gas and oil industry dominated area including the town of Usinsk

The authors cite coal mining and combustion as the principal source of SO_2 emissions and heavy-metal pollution in the Usa Basin. The methods used to determine the perceptions of environmental issues differed between urban and rural participants. Semi structured interviews on environmental perceptions, awareness of socioeconomic problems, and solutions to environmental problems were used for the urban dwellers, who were industrial workers, teachers, and managers/administrators. Rural participants were mainly from the reindeer industry and were interviewed informally with guiding questions and field notes recorded. The exception to this method for rural participants was for those who were deemed ‘experts’ (ie managers and administrators) who instead received semi structured questionnaires. The number of interviews undertaken in the two study areas was about equal.

The results showed that social problems were perceived to be of higher priority than environmental issues for both the Usinsk and Vorkuta participants. Although the town of Vorkuta has more scientific evidence of environmental problems than Usinsk, residents of Usinsk reported worse perceptions of environmental issues than residents from Vorkuta – possibly as a result of an oil spill in Usink in 1994 which was mentioned by every participant from there as a concern. Residents of Vorkuta cited air pollution as the biggest environmental problem and based their observations on direct experience such as respiratory problems, discoloration of clothing, and discoloration of snow. Participants from both towns reported concern over water quality and that this has resulted in infringements on recreational activities such as fishing and swimming. Residents from both Usinsk and Vorkuta were both concerned for their health due to polluted water.

The quantitative component of the study undertaken as part of the TUNDRA project assessed pollution by satellite imagery of vegetation changes, lake water and sediment analysis, and snow, soil and lichen chemistry. This was undertaken across three areas covering industrial to pristine locations. Scientific measurements showed elevated contaminants associated with coal mining and coal combustion in lakes, soil, and snow samples. Furthermore, there were more changes to vegetation around Vorkuta than Usinsk, although environmental concerns are more prominent in Usinsk which was relatively unpolluted. The authors suggest this is due to the gradual nature of the pollution as opposed to the acute nature of the oil spill that occurred in 1994 in Usinsk. This constitutes environmental injustice as residents of Vorkuta were largely unaware of the pollution levels in their town due to the hidden nature of levels of many contaminants. It is noted by the authors that the rise of environmental activism in several communities has resulted in residents collecting their own data on the health situation, a phenomenon they term ‘popular epidemiology’.

The main finding of the study was that residents’ perceptions of environmental pollution are not necessarily influenced by scientifically shown measures of pollution. Rural inhabitants were aware of vegetation changes but perceived them more gradually and when visible due to a very high level of pollution, such as an oil spill. The authors state that both perceived and measured levels of pollution are ‘real’ in their own right. The main limitation of this study was that the selection method of the participants was not made explicit. The scientific measurements appear to be thorough.

Water quality and human occupations (activities)

The study by Blakeney and Marshall of water pollution in the Letcher County of Kentucky also explored the link between water qualities and human occupation. The authors defined ‘occupation’ as all human activities, not just employment (Blakeney & Marshall, 2009). The study involved face to face interviews with Letcher County health professionals (n=122) on water and occupation, and telephone interviews with Letcher County adult citizens (n=40) about their experiences with water.

The analyses of the interviews were presented in three key themes of i) occupational injustice/ occupational deprivation, ii) occupational imbalance and iii) occupational alienation indicating that Letcher County residents experience occupational injustice in a multifaceted way. The study concluded that the watershed in the Letcher County of Kentucky has been polluted due to coal mining in the area, and that local social injustices due to water quality degradation are directly related to mining. Examples given were:

- reduced ability to gain income by growing and selling local produce
- unsafety of garden produce irrigated with contaminated water
- restrictions on outdoor activities including loss of recreational options such as swimming
- unpleasant odour and dingy appearance of clothes washed in the local water supply
- the need to plan water use eg visit relatives/friends with a cleaner water supply for cooking water
- the imperative to use water filters and the time and effort required to maintain these
- the imperative to buy bottled water and the added cost of this
- restrictions to facilities and everyday habits most Americans take for granted

The authors acknowledge limitations to the study such as interviews being confined to those who had telephones. This is particularly pertinent since the Letcher County has a high poverty rate with many of the poorest families having no telephone, thus being automatically excluded from participation in the study. The possibility that the study did not include residents who did not believe there was a problem was also acknowledged as a possible limitation.

Social and economic impacts

Riva and colleagues (2011) used data from the Health Survey for England to determine if i) there was a 'coalfield effect' on health irrespective of socioeconomic demographics, ii) if such an effect is mediated by deprivation, social cohesion or rurality and iii) if there are geographical or social inequalities in health across coal field areas. The authors contextualise their study by outlining historical adverse social impacts of coal mining in England such as periods of heavy job losses and a legacy of environmental degradation.

The study found that people in former coalfields are significantly more likely to report long term limiting illnesses (LTLI) and poorer self rated health, and that this is independent of socioeconomic factors. Furthermore, the 'coalfield effect' was still found to be significant for LTLI after considering area level deprivation, social fragmentation, and rurality. Rural areas tended to report more ill health, but not LTLI or mental health problems. Overall mental health was not significantly different across former coalfields when compared with England as a whole. The study included analysis of individual level characteristics, including health behaviours such as smoking and alcohol status. Accounting for individual characteristics explained some, but not all, of the variation in health across coalfields.

Limitations include the cross-sectional nature of the study which did not allow consideration of in and out migration effects or a longitudinal study of the exposure to the socioeconomic conditions. Some of the areas studied had undergone specific regeneration programmes funded mainly by the government and delivered through both public and private schemes. The reference to the various regeneration projects also raised the issue of who should be paying for regeneration programmes; they appear to be mostly government sponsored and therefore represent an additional cost resulting from but not borne by the coal industry.

Closer to home, Lockie and colleagues (2009) undertook local social impact assessments (SIAs) in 2002-03 and 2006-07, approximately five and nine years after the Coppabella Mine commenced operations at Nebo in the coal-rich Bowen Basin area of Central QLD, Australia. The SIAs included mine workers, residents, local businesses and local aboriginal communities. The SIAs were conducted outside the QLD legislative framework for environmental impact assessment and project approval on the basis that such frameworks are limited to new projects and therefore are unable to account for cumulative impacts of mining projects. The project was funded by Macarthur Coal.

The methodology was based on two phases. Phase 1 included a scoping exercise to determine the potential positive and negative impacts of mining cited in other similar studies, and Phase 2 was a baseline assessment of impacts and mitigation strategies. Issues examined included demographic changes, housing, social integration, traffic and fatigue, business opportunities and constraints, cultural heritage, and opportunities for indigenous people.

The analysis showed that in 2003, many of the social impacts evident at that stage of the resource community cycle related to a failure by the community to capture positive benefits, particularly economic benefits, despite increasing dependence on mining for employment and income. At the same time, whilst mining was responsible for only a small increase in population, rapid demographic and social changes occurred which undermined the ability for the community to generate alternative economic and cultural capital to assist in enduring future mining sector downturns. However, the results also acknowledged that Macarthur Coal had engaged with some stakeholders—indigenous groups in particular—in a manner that enhanced capacity and social capital.

The cumulative impact of multiple mine expansions and developments from 2003-06 saw the magnification of these issues and the emergence of several acute social impacts, including severe shortages of skilled labour in other industries; reduced access to and affordability of accommodation; increased road traffic and fatigue-related road accidents; increased pressure on emergency services (particularly those provided by volunteers); and increases in criminal and other anti-social behaviours. The increase in anti-social behaviour between the two studies appeared to be linked to the declining density of acquaintanceship and informal surveillance associated with population growth.

The most apparent effect was the exponential growth in the temporary resident population between 2003-06. The report also noted the progressive masculinisation of the permanent resident population and that a large and demographically unbalanced mobile population reduces the attractiveness of Nebo as a residential location for women and families. Overall the changes between the SIAs appear fairly limited but with both positive and negative effects. A comparison with the area before the mine commenced would have been useful.

Author’s comments

We found only a few studies in the international literature that directly set out to explore and analyse social injustice in relation to coal mining and coal combusting in power stations. Further, given the socio-cultural, economic differences and differences in mining practices and regulations between Australia and other countries (Russia, for example) it is difficult to know with certainty, to what degree some findings might be applicable to the Australian context. Nonetheless, local anecdotal reports point to a high level of stress, social distress and fears about local environmental and social changes, and about health impacts and it is clear from the literature that this in itself constitutes a social injustice.

The lack of definitive evidence to address uncertainties about the applicability of the international evidence further adds to the argument that there is a need for well designed qualitative studies of the social justice impacts of mining to be undertaken locally.

Research Question 4

Is there an association between coal mining and social injustice in the Hunter Region of NSW?

Introduction

This section deals with social injustice in relation to coal mining and coal combustion in coal-fired power stations specifically in the Hunter Region.

The literature searches for this question yielded six relevant peer reviewed journal articles which explored social impacts associated with coal mining specifically in the Hunter Region. The authors of these studies used mainly qualitative methods to explore issues and impacts associated with coal mining and combustion through the perceptions and experience of local residents.

We also reviewed three relevant non-peer reviewed reports. One of these was published by the Hunter Public Health Unit (Dalton, 2003), another by the Australian Coal Association Research Program (Brereton et al, 2008) and the third by the Australia Institute (Richardson & Denniss, 2011). These report did not all deal specifically with social injustice as a definitive concept but all explored key issues which fall under the rubric of social injustice such as air quality and other environmental issues, and unfair distribution of social and economic benefits and burdens.

The peer reviewed reports dealt with a range of social and environmental issues, such as the inequalities in power and influence between community and private interests. They also touch on the dilemma that faces governments everywhere: the trade off between the imperative for economic growth versus the physical and social well being of the community. We report this evidence under the following themes:

- Social distress and environmental injustice
- Asymmetry of power and influence
- Water access and rights
- Failure to protect.

These categories were generated from the literature rather than being pre-determined by the authors of this Report.

Summary of Evidence for Research Question 4

Social injustices associated with mining in the Hunter Region

The evidence presented in this section illustrates multiple examples and variations of social injustices associated with coal mining and combustion in the Hunter Region of NSW.

There are numerous anecdotal reports of local community concerns being ignored due to the perceived overall benefit of mining. Further, the lack to date of a population study to determine the health impacts of mining and power generation activity on local residents is seen by many local community members as evidence of the failure of relevant authorities to heed community concerns. Broadly, these concerns fell under the following themes:

Social distress and environmental injustice

- Feelings of loss and distress resulting from changes in the local environment (‘solastalgia’)
- Feelings that the local was marginalised and not accorded full stakeholder status
- Deepening social divisions within the community due to the increasingly unequal distribution of wages, inequalities in land compensation arrangements, and changes to the organisational structure of work
- Concerns over the cumulative impact of mining on human health
- Environmental damage and the likelihood of this affecting future generations
- Concerns about air quality, noise pollution and negative impacts on human and environmental health associated with coal-related pollution.

Asymmetry of power and influence

- Difficulties obtaining crucial information disempowers local communities and works to ‘divide and rule’ communities
- Conflicting interest within authorities, eg the NSW Department of Primary Industries (formerly the NSW Department of Mineral Resources) is charged with regulating the mining industry but is also a major mining advocate
- Claims on resources such as land have become politicised and contested with asymmetries in power favouring the mining industry.

Water access and rights

- The mining industry obtains preferential water rights through the changes to the NSW water licensing system. Since 2005 this system uses classifications to determine priority uses of water and grades coal mining as a higher priority than pastoral industries.

Failure to protect

- This refers specifically to the failure of policy makers - both government and industry - to exercise the ‘precautionary principle' and adequately protect local communities from real and/or perceived risks and harms.

The evidence we have reviewed from the formal literature about social injustice in relation to coal mining in the Hunter Region gives considerable credence to recent and current anecdotal reports on this subject.

Detailed Description of the Evidence for Research Question 4

Social distress and environmental injustice

The first of the six research articles described the early stages and preliminary results of an ongoing study of environmental change and human distress in the Upper Hunter Valley (Connor et al, 2004). This area comprises Murrurundi, Scone, Muswellbrook, Singleton and Merriwa which are also home to rural industries of farming and grazing, race horse breeding and wine growing. The authors discuss historical changes of land use from the previous two centuries and use the term 'solastalgia' (derived from nostalgia) to describe the feelings such changes can evoke. The study explored residents' understandings and perceptions of environmental change, as well as local responses to the changes. In addition, the study reports the threats that arise from the expansion of open-cut mining and other industrial activities in the area. The authors identify indicators of distress linked to environmental degradation (emotional, physical, behavioural and social), as well as dimensions of individual's place identity and attachment to locality.

The researchers gathered and analysed qualitative data from i) in-depth interviews with key informants, ii) group interviews, and iii) semi-structured surveys of community residents. Three broad interrelated themes emerged which characterise the respondents' expressions of distress as:

- threat to ecosystem health
- threat to personal health (physical and mental)
- perceptions of being subject to environmental injustice

Excerpts from the interviews exploring these themes note that although respondents acknowledged that mining brings regional economic benefits, they felt that social divisions had deepened due to the associated high wages and changes to the organisation of work. Respondents also stated that there has been a loss of environmental quality, a rise in living costs, and social disruption from the high resident turnover. They felt that pollution and land compensation arrangements created 'winners' and 'losers' among those whose land was bought outright versus those left on the fringes of open-cut mines respectively. Concerns about negative health effects from mining such as respiratory illnesses and cancers were common.

A follow up study by the same group (Higginbotham et al, 2006) built on the initial findings by developing and validating a survey instrument known as the environmental distress scale (EDS). The study tested the ability of the EDS to discriminate between individuals exposed to different levels of environmental disturbance (discriminatory ability) as well as measurement precision (internal consistency, reliability and repeatability), and appraised the contribution of 'solastalgia' as a key component of environmental distress. Participants in this postal survey were randomly selected from two sites: i) Singleton - an area of high environmental disturbance from mining and ii) Dungog - an area of low environmental disturbance from mining. The overall survey response rate was 41% and the demographics of respondents from both areas were similar. The results showed that the two groups did not differ on their perceptions of the trustworthiness of environmental information sources, rating both industry and state government information as dubious. However, there were significant differences in the scores for environmental distress with the Singleton respondents reporting significantly more personally observed and experienced environmental hazards, perceived threat and health impact hazards, and feelings of 'solastalgia'. Residents of Singleton were less likely to be upset by thoughts of having to leave. Although the study does not explicitly address the reason for this, it suggests that it may relate to the extent of the changes in their area. When the components of the EDS scale were combined to give a single score, the difference between the two groups remained significant.

In a study of the Hunter Valley Higginbotham and colleagues (2010), define environmental injustice as: *"the disproportionate exposure of socially vulnerable groups to pollution and its associate effects on health and the environment, as well as the unequal environmental protection provided through laws, regulations and enforcement"* and further break this concept down to:

a) *distributive environmental injustice* ie when vulnerable groups are disproportionately affected by environmental hazards

b) *procedural injustice* which refers to the inequitable distribution of environmental hazards in terms of underlying socio-cultural factors, including the burden of risk imposed on culturally disadvantaged groups and lack of public participation in decision making process.

They cite evidence of increasing emissions in the Upper Hunter Valley of fine particles and other pollutants over the previous decade. Their study also explores some of the impacts associated with increased fine particles and pollutants, such as community concerns about air pollution and the rise in complaints to the Environmental Protection Authority Hotline from the major residential centres of Muswellbrook, Singleton and Maitland. They discuss the intensification of community pressure on government for a health study in the Upper Hunter and note that residents were being marginalised by the relevant authorities, thus resulting in procedural injustice as community and environmental groups were not being considered as stakeholders. The example was given of a Federal Minister from a Hunter electorate at the time who was cited as suggesting that opponents to the Anvil Hill Mine were conducting a 'jihad' with the intention of closing down the entire coal industry.

The authors comment on the changing position of Local Government from being generally supportive of coal mining to becoming increasingly concerned about the cumulative impact of mining on human health, and joining the call for a local health study. They also point to a decrease in the ability of Local Government to facilitate action to address the concerns of local communities. For example, since 2005 changes in state planning laws removed the input of Local Government in the approval process for of mining projects, thereby effectively eliminating the key procedural avenue for local influence in decisions about mining expansion.

In response to increasing concerns from community groups about the cumulative health impacts from growing industrial development, the HNEAHS Public Health Unit (Dalton, 2003) reported on surveys of 665 selected residents of the Hunter Valley aged over 15 years. Environmental Health Managers in all 11 LGAs and members of the Area Health Services Health Councils were also surveyed. The results indicated that air pollution followed by water pollution were the major concerns for all three groups. Motor vehicle emissions were also a primary source of concern, and it should be noted that numerous reports refer to the impact of noise, air pollution, and road trauma associated with transport involved in coal mining. The survey found that environmental health concerns varied significantly by LGA and appeared to be influenced by road/traffic density and large industrial polluters such as coal mines and power stations. There were high rates of concern about air pollution in Singleton and Muswellbrook specifically, both of which are located near coal mines and power stations.

Despite increasing concerns about climate change neither the government nor the mining industry appear to have been called to account for the environmental ramifications of the $922 million(AUD) expansion of the Newcastle coal port (Connor et al, 2009).

Asymmetry of power and influence

An Australian Coal Association Research Program (ACARP) sponsored study examining the cumulative impact of mining, using Muswellbrook as the focal point, under the four headings of i) employment, ii) visual amenity, iii) water quality in the Hunter River, and iv) social impacts (Brereton et al, 2008). The Project Steering Committee comprised coal industry members who felt that the community was 'overconsulted' and therefore proceeded to review mine complaints instead of undertaking further consultation with the community. Nonetheless, the researchers conducted and reported on four focus groups, including one with an anti-mining group, and members of mine community consultation committees. Themes emerging from these focus groups referred to perceived social injustices such as:

- the disproportionate power of the mining industry
- the perception that regulatory authorities sided with industry and arbitrated without the interests of the community in mind
- changes to legislation in favour of the mining industry

Economic benefits from employment associated with mining were acknowledged. However this was tempered by perceptions that there were increasingly limited opportunities for employment of locals. Additionally, employment patterns at mines were felt to have a negative impact on community activities such as volunteer work. Social cohesion was not seen to be eroded, as the number of displaced landholders was too small to have a discernable impact. There was limited discussion of visual amenity (the extent to which mined land was visible from Muswellbrook).

Connor and colleagues (2009) examined the arguments employed by both pro and anti-mining groups in relation to the proposal for the Anvil Hill Coal Mine in the Hunter Valley. They explored changes in environmental knowledge and oppositional practices of coal-affected residents in the Hunter Valley. They commented on the growth and improved organisation of mining opposition into formal civil society groups such as the Anvil Hill Project Watch Association. In addition, the authors noted that the incorporation of global issues such as climate change into the community discourse has given local communities more political leverage - as demonstrated by a successful legal challenge to the Land and Environment Court in December 2006. However, despite inadequate environmental assessments relating to the Anvil Hill Mine, the NSW government approved the project in 2007 and further legal challenges were unsuccessful.

The authors commented on difficulties experienced by protestors in obtaining information from the various government departments. 'Gag clauses' commonly imposed by mining companies in land acquisition contracts were noted as a power issue which can effectively serve to generate divisions in the community through what appears to be a divide and rule tactic. They also note the imbalance of resources between the mining industry and its opponents, and that the mining industry generally enjoys a closeness to state and corporate power that civil society does not. The authors also cited the state approval, in 2007, of the $922 million(AUD) expansion of the coal port of Newcastle as an example of the systemic entrenchment of political capital in favour of commercial mining interests. This is because public sector investments of this magnitude assure ongoing state government commitment to further coal mining expansion in order to support export markets, thereby justifying the investment.

In this article, Connor and colleagues described the mining industry's role in pro-industry lobbying, analysing how it obtains political capital (by making the case of perceived economic benefits), and how it gains bilateral political party support through membership of regional organisations such as business chambers. The authors take the stance that in the face of continuing and growing concern about climate change, political support is not sufficient to give mining companies a 'social licence to operate'. This concept is defined by the NSW Minerals Council (the peak industry body) as the unwritten social contract that a company earns and maintains through good performance on the ground and social trust.

Higginbothom and colleagues (2010) also analysed the political economy of coal mining in NSW. They cited mining royalties to the state government estimated at $1.3 billion(AUD) for 2009-10, and point out that this presents a strong incentive for the government to allow ongoing expansion of coal mining. They note that this has resulted in the cynical view among residents and mining opponents that it is not in the interest of the NSW Government to examine the health effects of mining. The authors discuss the imbalance of power and access to information between mining companies and community groups, and that self regulation of air quality and pollution by mining companies has become contentious due to a lack of action on pollution breaches. The authors also state that there is an inherent conflict of interest which facilitates procedural injustice, since the NSW Department of Primary Industries (formerly the NSW Department of Mineral Resources) is responsible for coal mining regulation but is also the primary mining advocate. In addition, the authors cite the absence of an independent air monitoring scheme which could assist with a health study and risk analysis, and that there is no consideration for a more comprehensive cumulative risk assessment process that would enable a health impact assessment to be undertaken alongside the environmental impact assessment process.

The cost of the life cycle of coal to the community - notably the cost of electricity generation - is immense. The Australia Institute (Richardson & Denniss, 2011) cites evidence that government subsidies to support the extraction of fossil fuels in Australia amounts to $10 billion(AUD) annually. The authors highlight areas indicated by the Productivity Commission in which state governments provide assistance to the mining industry as:

- the provision of a variety of tax concessions eg holiday, payroll
- fast tracking development arrangements
- the provision of cheap water and power
- the provision of infrastructure to support mining operations eg airports, ports, housing for employees
- lax regulation of environmental impacts

Water access and rights

Researchers from the same group undertook a further study responding to a new proposal for the first open-cut mine by Bickham Coal in the town of Murrurundi in the Upper Hunter Valley (Connor et al, 2008). The researchers noted that there is increasing contestation over water in relation to the competing needs of the mining industry and traditional pastoral industries. The article discusses the traditional methods of negotiations between local farmers in the area concerning water allocation, as well as the measures that they have been taking to adapt to the decreasing availability/greater demand for water. The article also reports on the policy changes encapsulated in the NSW Water Management Act (2000) which separates land and water rights, and establishes a water licence system using graded classifications to aid with the trading of water as a commodity. With these policy changes mining companies' water licenses have been rated as 'high security' whilst water for farming use is given the lower licence rating of 'general security'.

In particular, Connor and colleagues describe the struggles of the local communities and environmentalists to combat the Bickham Coal mine on the basis of its potential to damage local landscape and waterways, notably the Pages River. Evoking concepts of custodianship of the land by both indigenous and non-indigenous residents, and the "sentience of nature and its inalienable right to exist", the authors report strong feelings of community anger, revulsion and resentment about the potential carnage to the landscape. In addition, the potential loss of history, heritage and place occasioned by the mine proposal are explored. The key issues raised are central to the concept of social injustice. These include inequalities in water rights; enforced changes to the pastoral nature of the local industries; and the disregard for the area's more distant history as hunting and fishing grounds for the Wanarua people whose descendants still maintain a relationship with this land.

The authors conclude that conflicts over critical resources such as water will multiply as the push for more mines in the Hunter Valley escalates, postulating that fresh water is and will be "unable to satisfy the principle of plenitude ie enough so that no-one needs to fight over it". They discuss access as a matter of political contestation where those with greater power, such as coal companies, succeed in achieving their objectives at the expense of less powerful groups. Connor and colleagues go on to point out that, in this type of scenario, the precautionary principle (the burden to prove the absence/lack of harm) is often overlooked in favour of commercial interests. Nonetheless, mining opponents can and do take advantage of the deficits and uncertainties in aspects of scientific modelling in the wider global climate change arena to challenge the mining industry. Connor and colleagues also note that climate change science has not yet become part of the legal-bureaucratic framework of state government environmental planning and mine approvals and that there are powerful interests against this.

Failure to protect

In their analysis of coal mining related environmental injustice in the Hunter Valley, Higginbotham and colleagues (2010) discuss pressure from the local community, Local Government, and local medical practitioners for a health study in the Upper Hunter. They state that the barriers to achieving a health study include a "lack of political will and regulatory inertia", thereby citing both political and institutional failures. The absence of an independent air monitoring mechanism and a more comprehensive cumulative assessment process is stated by the authors as a clear violation of social justice since policy makers have a duty to enact the 'precautionary principle' into policy making (ie to act before rather than after damage has occurred). While the authors acknowledge constraints in terms of study design and assessment issues, they state that the 'precautionary principal' is of paramount importance since intergenerational environmental injustice occurs as a result of the long time lag between certain risk exposures and disease onset, citing asbestos as an example.

Relevant to this topic, Harris and colleagues published a peer reviewed report based on a survey that examined the focus of environmental assessments (2009). The findings of the survey led Harris and colleagues to conclude that considerations of health in the NSW requirements are glaringly absent, or at best vague and indirect, in environmental assessments of new development applications of any kind.

Author's comments

There is a surprisingly rich literature describing various aspects of the social injustice in relation to coal mining activity in the Hunter Region. This evidence is predominantly qualitative in nature and is consistent with the evidence reviewed for Research Question 3 which looks at a broader geographical research base.

Some of the studies we reviewed note the absence of a specific study to examine the health impact/s of coal mining and combustion in the Hunter Region, and cite this as a source of serious concern to the local community. It should be noted that, at the time of writing this report we understand that the NSW Ministry of Health is planning to undertake a study of the health impacts of air pollution in conjunction with air quality monitoring stations.

Section 4:

COSTS AND POLICY IMPLICATIONS

COSTS & POLICY IMPLICATIONS

The literature searches for this Report did not specifically focus on the financial cost of coal to society. However, some of the studies identified to answer the research questions included information on costs.

For example, elevated mortality rates in Appalachian coal mining areas have been examined in terms of value of statistical life (VSL) lost relative to the economic benefits of the coal mining industry (Hendryx & Ahern 2009). The value of statistical life is an estimate of the financial value society places on reducing the average number of deaths by one. Mortality estimates across four county groups (Appalachia with high levels of coal mining, Appalachia with lower mining levels, Appalachia without coal mining, and other counties in the nation) were converted to VSL estimates and compared with the economic contribution of coal mining. Before adjusting for variables, the yearly number of excess age-adjusted deaths in coal mining areas ranged from $3,975 to $10,923(USD), depending on the years studied and the comparison group. Corresponding VSL estimates ranged from $18.563 to $84.544 billion(USD), greater than the $8.088 billion(USD) contribution of coal mining to the economy. After adjusting for variables that affect mortality risk, the corresponding VSL estimates were greater than the economic contribution of coal mining. Consequently, the authors concluded the human cost of the Appalachian coal mining economy outweighs its economic benefits.

Another study of coal-fired power stations examined the uncertainties and variability associated with estimating health related costs (Levy et al, 2009). This study analysed data for 407 coal-fired power stations across the US focussing on premature mortality associated with $PM_{2.5}$. The authors modelled $PM_{2.5}$ emissions and the influence of SO_2 and nitrogen oxide emissions on secondary particle formation. Mortality estimates of $PM_{2.5}$ were based on a central estimate of a 1.2% increase in mortality per ug/m3 increase in average annual $PM_{2.5}$ levels. VSL was used in the cost estimation. The median of the plant-specific uncertainty distributions damages ranged from $30,000 to $500,000(USD) per ton of $PM_{2.5}$, $6,000 to $50,000(USD) per ton of SO_2 and $500 to $15,000(USD) per ton of nitrogen oxide. This equated to an additional cost of $0.02 to $1.57(USD) or 2c to 157c per kilowatt-hour (kW/h) of electricity generated. The variability in damage estimates was mostly explained by population exposure per unit emissions, and meteorological conditions and distance from the power station affecting population exposure. The authors note that the costs are large relative to the consumer cost of electricity and if these were included in the consumer cost it would have significant ramifications for fuel choice. They note that this would make older power stations uneconomic, due to their less efficient technology. Such modelling would be difficult to undertake in Australia due to lack of $PM_{2.5}$ data.

Another US analysis evaluated and monetised all stages in the life cycle of coal, where possible, based on figures for the coal mining region of Appalachia (Epstein et al, 2011) including extraction, transport, by-products/waste and combustion. The authors included health costs and the cost of measures to reduce CO_2, such as carbon capture and storage. Some impacts such as ecological damage were not assigned a monetary value. The total cost estimated was $345 billion(USD), or 17.8c/kW/h ($0.17/kWh) of electricity generated. In a study comparing the cost of health impacts across various methods of generating electricity, Markandya & Wilkinson (2007) attributed 24.5 deaths per terawatt hours of coal combustion. However, some of these costs were generated from occupational health impacts.

An Australian report estimated the costs of the negative health and environmental externalities of coal mining in Australia (ATSE, 2009) and put the health costs associated with coal-fired power stations at $2.6 billion(AUD) per year. The cost of the combined health and environmental impacts of black coal as an energy source was estimated at $42(AUD) per megawatt-hour.

Implications for policy and planning

There is no current, definitive local evidence that comprehensively describes the associated health and social costs of coal extraction and combustion. There is therefore no solid basis for determining the balance of public harm versus public good. The health, social and financial costs of coal mining and combustion may well outweigh any benefits and additional burdens on the whole society since government subsidies and benefits to the mining industry are rarely included in cost calculations (Richardson & Denniss, 2011). Further, many of the negative consequences of the disruption, displacement and lost opportunities such as occupational tradition and choice, and all of the irreparable environmental damage caused by coal mining and combustion activity in Australia will not stop with the present but will likely have negative impacts on future generations – and it is probable that these effects will continue long after our coal reserves are exhausted.

These impacts have wide implications for policy and governance, and require prompt and thorough attention to reviewing and reforming government policies and regulations around the licensing and operating of coal mines and coal-fired power stations. While awaiting such reforms there is an pressing need for a policy response to i) ensure transparency in arrangements between government and the mining industry, ii) redress tax anomalies, iii) enforce standards of practice and community safeguards such as mandatory health impact assessments and penalties for non compliance with these.

Most importantly, well designed local studies capable of identifying or refuting associations between coal mining and health need to be commissioned and undertaken as a matter of urgency. Until this evidence is available it is not possible to accurately weigh up and meaningfully debate the benefits versus the harms of coal mining for Australia.

REFERENCES

Aekplakorn WD, Loomis D, et al (2003). Acute effect of sulphur dioxide from a power plant on pulmonary function of children, Thailand. International Journal of Epidemiology 32(5): 854-61.

Ahern M, Mullett M, et al (2011a). Residence in coal-mining areas and low-birth-weight outcomes. Maternal and Child Health Journal 15(7): 974-979.

Ahern M, Hendryx M, et al (2011b). The association between mountaintop mining and birth defects among live births in central Appalachia, 1996-2003. Environmental Research 111(6): 838-846.

ATSE (2009). The Hidden Costs of Electricity: Externalities of Power Generation in Australia. Australian Academy of Technological Sciences and Engineering.

Australian Bureau of Statistics (2011). National Regional Profile 2006-2010. Australian Bureau of Statistics; 2011, Available at: http://www.ausstats.abs.gov.au/ausstats/nupmaps.nsf/NEW+GmapPages/nationals+regional+profile. Accessed: 23.01.2012.

Australian Coal Association (2008). Coal & its uses - Coal through history. Australian Coal Association, Available at: http://www.australiancoal.com.au/coal-and-its-uses_coal-uses_coal-through-history.aspx. Accessed: 12.12.2011.

Australian Department of Resources Energy and Tourism (2011). Resources: Australia's Coal Industry. Australian Government Department of Resources, Energy and Tourism, Available at: http://www.ret.gov.au/resources/mining/australian_mineral_commodities/Pages/australia_coal_industry.aspx. Accessed: 23.09.2011.

Bem H, Wieczorkowski P, et al (2002). Evaluation of technologically enhanced natural radiation near the coal-fired power plants in the Lodz region of Poland. Journal of Environmental Radioactivity 61(2): 191-201.

Bencko V, Rames J, et al (2009). Ecological and human health risk aspects of burning arsenic-rich coal. Environmental Geochemistry and Health 31(Suppl 1): 239-243.

Biopharm Australia (2011). Submission to the better regulation of agricultural and veterinary chemicals policy discussion paper. Biopharm Australia Pty Ltd, Bondi.

Blakeney AB & Marshall A (2009). Water quality, health, and human occupations. The American Journal of Occupational Therapy 63(1): 46-57.

Boffetta P, Cardis E, et al (1991). Cancer risks related to electricity production. European Journal of Cancer and Clinical Oncology 27(11): 1504-1519.

Brabin B, Smith M, et al (1994). Respiratory morbidity in Merseyside schoolchildren exposed to coal dust and air pollution. Archives of Disease in Childhood 70(4): 305-312.

Brereton D, Moran C, et al (2008). Assessing the cumulative impacts of mining on regional communities: an exploratory study of coal mining in the Muswellbrook area of NSW. Australian Coal Association Research Program, Brisbane.

Brook RD, Franklin B, et al (2004). Air pollution and cardiovascular disease. Circulation 199(1): 2655-2671.

Castleden WM, Shearman D, et al (2011). The mining and burning of coal: effects on health and the environment. Medical Journal of Australia 195(6): 333-5.

Connor L, Albrecht G, et al (2004). Environmental change and human health in Upper Hunter communities of New South Wales, Australia. EcoHealth 1(Suppl 2): 47-58.

Connor L, Higginbotham N, et al (2008). Watercourses and discourses: Coalmining in the upper Hunter Valley, New South Wales. Oceania 78(1): 76-90.

Connor L, Freeman S, et al (2009). Not just a coalmine: Shifting grounds of community opposition to coal mining in Southeastern Australia. Ethnos 74(4): 490-513.

Dalton, C (2003). Environmental health concerns in the Hunter. Hunter Public Health Unit, Wallsend, NSW.

Doctors for the Environment Australia (2011). Submission to the Rural Affairs and Transport References Committee Inquiry into management of the Murray Darling-Basin - impact of mining coal seam gas. Doctors for the Environment Australia, Pasadena.

Dubnov J, Barchana M, et al (2007). Estimating the effect of air pollution from a coal-fired power station on the development of children's pulmonary function. Environmental Research 103(1): 87-98.

Epstein PR, Buonocore JJ, et al (2011). Full cost of accounting for the life cycle of coal. Annals of the New York Academy of Sciences 1219(1): 73-98.

Esch L, Hendryx M (2011). Chronic cardiovascular disease mortality in mountaintop mining areas of central Appalachian states. Journal of Rural Health 27(4): 350-357.

Garcia-Perez J, Pollan M, et al (2009). Mortality due to lung, laryngeal and bladder cancer in towns lying in the vicinity of combustion installations. Science of the Total Environment 407(8): 2593-2602.

Ghose MK & Banerjee SK (1995). Status of air pollution caused by coal washery projects in India. Environmental Monitoring and Assessment 38(1): 97-105.

Ghose MK & Majee SR (2007). Characteristics of hazardous airborne dust around an Indian surface coal mining area. Environmental Monitoring and Assessment 130(1-3): 17-25.

Goren AI, Hellmann S, et al (1995). Use of outpatient clinics as a health indicator for communities around a coal-fired power plant. Environmental Health Perspectives 103(12): 1110-1115.

Goren AI & Hellmann S (1997). Has the prevalence of asthma increased in children? Evidence from a long term study in Israel. Journal of Epidemiology and Community Health 51(3): 227-232.

Gostin LO (2007). Why should we care about social justice? Hastings Center Report 37(4): 3.

Halliday JA, Henry RL, et al (1993). Increased wheeze but not bronchial hyper-reactivity near power stations. Journal of Epidemiology and Community Health 47(8): 282-286.

Harris PJ, Harris E, et al (2009). Human health and wellbeing in environmental impact assessment in New South Wales, Australia: Auditing health impacts within environmental assessments of major projects. Environmental Impact Assessment Review 29(5): 310-318.

Hendryx M, Ahern MM, et al (2007). Hospitalization patterns associated with Appalachian coal mining. Journal of Toxicology and Environmental Health Part A 70(24): 2064-2070.

Hendryx M & Ahern MM (2008). Relations between health indicators and residential proximity to coal mining in West Virginia. American Journal of Public Health 98(4): 669-671.

Hendryx M (2009). Mortality from heart, respiratory, and kidney disease in coal mining areas of Appalachia. International Archives of Occupational and Environmental Health 82(2): 243-249.

Hendryx M & Ahern MM (2009). Mortality in Appalachian coal mining regions: The value of statistical life lost. Public Health Reports 124(4): 541-550.

Hendryx M & Zullig KJ (2009). Higher coronary heart disease and heart attack morbidity in Appalachian coal mining regions. Preventive Medicine 49(5):355-359.

Hendryx M, Fedorko E, et al (2010). A geographical information system-based analysis of cancer mortality and population exposure to coal mining activities in West Virginia, United States of America. Geospatial Health 4(2): 243-256.

Henry RL, Abramson R, et al (1991a). Asthma in the vicinity of power stations: I. A prevalence study. Pediatric Pulmonology 11(2): 127-133.

Henry RL, Bridgman HA, et al (1991b). Asthma in the vicinity of power stations: II. Outdoor air quality and symptoms. Pediatric Pulmonology 11(2): 134-140.

Higginbotham N, Connor L, et al (2006). Validation of an environmental distress scale. EcoHealth 3(4): 245-254.

Higginbotham N, Freeman S, et al (2010). Environmental injustice and air pollution in coal affected communities, Hunter Valley, Australia. Health and Place 16(2): 259-266.

Hitt NP & Hendryx M (2010). Ecological integrity of streams related to human cancer mortality rates. EcoHealth 7(1): 91-104.

Howie J, Tong S, et al (2005). Air pollution and cardiopulmonary diseases in Australia: A review of epidemiological evidence. Environmental Health 5(1): 23-36.

Karavus M, Aker A, et al (2002). Respiratory complaints and spirometric parameters of the villagers living around the Seyitomer coal-fired thermal power plant in Kutahya, Turkey. Ecotoxicology and Environmental Safety 52(3): 214-220.

Levy JI, Baxter LK, et al (2009). Uncertainty and variability in health-related damages from coal-fired power plants in the United States. Risk Analysis 29(7): 1000-1014.

Liao Y, Wang J, et al (2010). Spatial analysis of neural tube defects in a rural coal mining area. International Journal of Environmental Health Research 20(6): 439-450.

Lockie S, Franettovich M, et al (2009). Coal mining and the resource community cycle: A longitudinal assessment of the social impacts of the Coppabella coal mine. Environmental Impact Assessment Review 29(5): 330-339.

Lockwood A, Welker-Hood K, et al (2009). Coal's assault on human health: A report from Physicians for Social Responsibility. Physicians for Social Responsibility, Washington.

Markandya A & Wilkinson P (2007). Electricity generation and health. The Lancet 370(9591): 979-990.

McConnel JR & Edwards R (2008). Coal burning leaves toxic heavy metal legacy in the Arctic. Proceeding of the National Academy of Sciences of the United States of America 105(34): 12140-12144.

Moffatt S & Pless-Mulloli T (2003). "It wasn't the plague we expected." Parents' perceptions of the health and environmental impact of opencast coal mining. Social Science & Medicine, August, 57(3): 437-451.

Mohorovic L (2004). First two months of pregnancy - critical time for preterm delivery and low birthweight caused by adverse effects of coal combustion toxics. Early Human Development 80(2): 115-123.

Mohorovic L, Petrovic O, et al (2010). Pregnancy loss and maternal methemoglobin levels: An indirect explanation of the association of environmental toxics and their adverse effects on the mother and the fetus. International Journal of Environmental Research and Public Health 7(12): 4203-4212.

New South Wales GenWeb Project (2011). Hunter Valley GenWeb. New South Wales GenWeb Project, Available at: http://www.worldgenweb.org/~ausnsw/regions/hunter.htm. Accessed: 03.09.2011.

NSW Department of Primary Industries (2009). 2009 New South Wales Coal Industry Profile. NSW Department of Primary Industries, Sydney.

NSW Department of Primary Industries (2011). Minerals and Petroleum. NSW Department of Primary Industries, Available at: http://www.dpi.nsw.gov.au/minerals/resources/coal/coal-industry. Accessed: 11.12.2011.

NSW Department of Trade and Investment (2012). NSW Regions: Hunter. NSW Department of Trade and Investment, Available at: http://www.business.nsw.gov.au/invest-in-nsw/regional-nsw/nsw-regions/hunter. Accessed: 23.01.2012.

NSW Health (2010a). Respiratory and cardiovascular diseases and cancer among residents in the Hunter New England Area Health Service. NSW Department of Health, North Sydney.

NSW Health (2010b). Analysis of BEACH general practitioner encounter data to examine the potential health effects of the mining industry and other exposures in Singleton, Muswellbrook and Denman. NSW Health, Environmental Health Branch, North Sydney.

Onder M & Yigit E (2009). Assessment of respirable dust exposures in an opencast coal mine. Environmental Monitoring & Assessment 152(1-4): 393-401.

Øvrebø S, Fjeldstad PE, et al (1995). Biological monitoring of polycyclic aromatic hydrocarbon exposure in a highly polluted area of Poland. Environmental Health Perspectives 103(9): 838-843.

Pearson JF, Bachireddy C, et al (2010). Association between fine particulate matter and diabetes prevalence in the U.S. Diabetes Care 33(10): 2196-2201.

Peled R, Friger M, et al (2005). Fine particles and meteorological conditions are associated with lung function in children with asthma living near two power plants. Public Health 119(5): 418-425.

Perera F, Li T-Y, et al (2008). Benefits of reducing prenatal exposure to coal-burning pollutants to children's neurodevelopment in China. Environmental Health Perspectives 116(10): 1396-1400.

Pesch B, Ranft U, et al (2002). Environmental arsenic exposure from a coal-burning power plant as a potential risk factor for nonmelanoma skin carcinoma: Results from a case-control study in the district of Prievidza, Slovakia. American Journal of Epidemiology 155(9): 798-809.

Pless-Mulloli T, Howel D, et al (2000). Living near opencast coal mining sites and children's respiratory health. Occupational and Environmental Medicine 57(3): 145-151.

Pless-Mulloli T, Howel D, et al (2001). Prevalence of asthma and other respiratory symptoms in children living near and away from opencast coal mining sites. International Journal of Epidemiology 30(3): 556-563.

Richardson D & Denniss R (2011). Mining the truth: The rhetoric and reality of the commodities boom. The Australia Institute, Canberra.

Riva M, Terashima M, et al (2011). Coalfield health effects: Variation in health across former coalfield areas in England. Health and Place 17(2): 588-597.

Tang D, Li T-Y, et al (2008). Effects of prenatal exposure to coal-burning pollutants on children's development in China. Environmental Health Perspectives 116(5): 674-679.

Tang D, Li T-Y, et al (2006). PAH-DNA adducts in cord blood and fetal and child development in a Chinese cohort. Environmental Health Perspectives 114(8): 1297-1300.

Temple JMF & Sykes AM (1992). Asthma and open cast mining. British Medical Journal 305(1): 396-397.

Thompson T, Martin P, et al (2011). Performance of agricultural and resource industries in the New South Wales Hunter Region. Australian Bureau of Agricultural and Resource Economics and Sciences. Regional Outlook Conference, Muswellbrook.

Tourism Research Australia (2010). Regional tourism profiles 2008/09 New South Wales: Hunter region. Department of Resources Energy and Tourism, Canberra.

Veugelers PJ & Guernsey JR (1999). Health deficiencies in Cape Breton County, Nova Scotia, Canada, 1950-1995. Epidemiology 10(5): 495-499.

Walker TR, Habeck JO, et al (2006). Perceived and measured levels of environmental pollution: Interdisciplinary research in the subarctic lowlands of northeast European Russia. Ambio 35(5): 220-228.

Wong R-H, Kuo C-Y, et al (2005). Increased levels of urinary 8-hydroxy-2ʹ-deoxyguanosine attributable to carcinogenic metal exposure among schoolchildren. Environmental Health Perspectives 113(10): 1386-1390.

Woodruff TJ, Parker JD, et al (2010). International Collaboration on Air Pollution and Pregnancy Outcomes (ICAPPO). International Journal of Environmental Research and Public Health 7(6): 2638-2652.

Yapici G, Can G, et al (2006). Lead and cadmium exposure in children living around a coal-mining area in Yatağan, Turkey. Toxicology and Industrial Health 22(8): 357-362.

Yogev-Baggio T, Bibi H, et al (2010). Who is affected more by air pollution - sick or healthy? Some evidence from a health survey of schoolchildren living in the vicinity of a coal-fired power plant in Northern Israel. Health and Place 16(2): 399-408.

Zullig KJ & Hendryx M (2010). A comparative analysis of health-related quality of life for residents of U.S. counties with and without coal mining. Public Health Reports 125(4): 548-555.

Zullig KJ & Hendryx M (2011). Health-related quality of life among central Appalachian residents in mountaintop mining counties. American Journal of Public Health 101(5): 848-885.

APPENDIX A

EVIDENCE TABLES FOR RESEARCH QUESTION 1

What specific diseases or other health problems are associated with coal mining in local communities?

Appendix A: Summary of Evidence for Research Question 1

Table 1: Coal mining – adults

Author, year country	Study type & method	Study population	Outcomes	Relevant results	Comments
Esch & Hendryx 2011 US	Retrospective study. Age-adjusted chronic CVD mortality rates from 1999-2006 for counties where MTM occurs were linked with county coal mining data in non-MTM areas.	404 records from four Appalachian states (Kentucky, Tennessee, Virginia and West Virginia). - 32 from MTM areas. - 58 from mining in non-MTM areas. - 314 from non-mining areas.	Mortality rates. Surface area of coal mines in MTM areas.	• Chronic CVD mortality rates were significantly highest in MTM areas, followed by mining in non-MTM areas, and lastly in non-mining areas F(2,401) = 32.35; p < 0.001. • After adjustment for covariates, mortality rates in MTM areas remained significantly higher and increased as a function of greater levels of surface mining. • Higher obesity and poverty rates and lower college education rates also significantly predicted CVD mortality overall and in rural counties.	Covariates included smoking, rural-urban status, gender, physician supply, obesity, diabetes, poverty, race/ethnicity, education and Appalachian county.
Hendryx 2009 US	Retrospective analysis. Age-adjusted mortality rates from 2000-2004 for heart, respiratory and kidney disease were investigated in relation to tons of coal mined.	Four county groups: - Appalachian counties with > 4 million tons of coal mined (n = 63). - Appalachian counties with < 4 million tons (n = 66). - non-Appalachian counties with coal mining (n = 97). - other non-coal mining counties across the US (n = 2,914).	Mortality rates from heart, respiratory and kidney disease.	• Mortality rates from chronic heart (RR =1 .28, 95% CI: 1.25-1.30), chronic respiratory (RR = 1.07, 95% CI: 1.04-1.10) and kidney disease (RR = 1.19, 95% CI: 1.13-1.25) were significantly higher in coal mining areas of Appalachian counties with the highest level of coal mining compared to non-mining areas. • Higher rates of acute heart (RR = 1.06, 95% CI: 1.04-1.08) and respiratory (RR = 1.05, 95% CI: 1.13-1.25) mortality were found for non-Appalachian coal mining counties.	Results were adjusted for gender, education, poverty, race/ethnicity, physician supply, rural-urban status, smoking and a Southern regional variable.

Author, year country	Study type & method	Study population	Outcomes	Relevant results	Comments
Hendryx & Ahern 2008 US	Retrospective analysis. Telephone survey data were merged with county-level coal production and other covariates to investigate the relationship between health indicators and proximity to coal mining.	16,493 residents of West Virginia aged ≥ 19 years. Survey response rate: 55%.	Self-reported health status. Rates of cardio-pulmonary disease, COPD, hypertension, lung disease and kidney disease.	• Residential proximity to heavy coal mining was significantly associated with self-reported poorer health status. • The highest level of mining (≥ 4 million tons) predicted greater adjusted risk for cardiopulmonary disease, lung disease, hypertension, COPD, kidney disease and poorer adjusted health status ($p < 0.005$).	Covariates included smoking, obesity, poverty, age, gender, income, education and presence or absence of health insurance. Individual smoking and occupational exposure to coal was not able to be assessed.
Hendryx & Ahern 2009 US	Retrospective analysis. Age-adjusted mortality rates and socioeconomic conditions in coal mining areas from 1979-2005 were converted to VSL estimates and compared the results with the economic contribution of coal mining.	Four county groups: - Appalachian counties with levels of coal mining above the median (n = 70). - Appalachian counties with levels of coal mining below the median (n = 69). - Appalachian counties without coal mining (n = 274). - other counties in the nation (n = 2,728).	VSL estimates.	• VSL estimates ranged from $18.563-$84.544 billion, with a point estimate of $50.010 billion, greater than the $8.088 billion economic contribution of coal mining. • After adjusting for covariates, VSL costs continued to exceed the benefits of mining.	Covariates included smoking, rural-urban location, gender, physician supply, a regional South variable, poverty, race/ethnicity and education.

Author, year country	**Study type & method**	**Study population**	**Outcomes**	**Relevant results**	**Comments**
Hendryx & Zullig 2009 US	Retrospective analysis. Using the 2006 US BRFSS data, self-reported CVD rates were compared between coal mining counties and other counties.	235,783 residents, aged ≥ 18 years, from 1,148 counties in the US. - Appalachian counties with coal mining (n = 9,330). - Appalachian counties without coal mining (n = 9,622). - Non-Appalachian counties with coal mining (n = 9,089). - Non-Appalachian counties without coal mining (n = 207,742).	Self-reported morbidity rates for CVD.	After adjusting for covariates, people in Appalachian coal mining areas reported significantly higher risks for: • CVD (OR = 1.22, 95% CI: 1.14-1.30). • Angina or CHD (OR = 1.29, 95% CI: 1.19-1.39). • Heart attack (OR = 1.19, 95% CI: 1.10-1.30).	Variables included coal mining, smoking, BMI, alcohol intake, physician supply, diabetes, age, race/ethnicity, education and income.
Hendryx et al 2007 US	Retrospective analysis. Hospitalisation data from 2001 were merged with county-level coal production figures.	93,952 patients from West Virginia, Kentucky and Pennsylvania.	Hospitalisation patterns.	Hospitalisation for COPD and hypertension were significantly elevated as a function of Appalachian coal mining: • For COPD, it increased 1% for each 1,462 tons of coal. • For hypertension, it increased 1% for each 1,873 tons of coal, and with higher rates for women.	Results were adjusted for age, gender, insurance, co-morbidities, hospital teaching status, poverty and county social capital. Smoking and obesity were not measured.
Hendryx et al 2008 US	Retrospective analysis. Contributions of smoking rates, socioeconomic variables, coal-mining intensity and other variables related to age adjusted lung cancer mortality were compared between counties from 2000-2004.	- Heavy Appalachian coal mining (n = 66). - Other Appalachian (n = 347). - Rest of the nation (n = 2615).	Age-adjusted lung cancer mortality rates.	Age-adjusted lung cancer mortality was significantly higher in Appalachia compared to the rest of the US; 67.06 vs. 56.55 per 100,000 (two-tailed t = 12.67, df = 3026; p < 0.001).	Results were controlled for gender, education, poverty, race/ethnicity, insurance, physician supply, rural-urban status, smoking, Southern state and Appalachian county. Individual exposure to both smoking and coal were not able to be assessed.

Author, year country	Study type & method	Study population	Outcomes	Relevant results	Comments
Hendryx et al 2010 US	Retrospective analysis. Two GIS techniques tested alternative specifications of exposure to mining activity in relation to the prediction of age-adjusted cancer mortality rates for 1979-2004.	West Virginian cancer mortality data from the CDC.	Age-adjusted cancer mortality rates.	Total (r = 0.51; p < 0.001), respiratory (r = 0.53; p < 0.001) and “other” (r = 0.44; p < 0.001) age adjusted cancer rates were more closely associated with GIS exposure measure to coal mining activities than tonnage measure.	The GIS techniques compared location of mines, processing plants, coal slurry impoundments and underground slurry injection sites relative to population levels to exposure based on tons mined at the county level. The analysis was controlled for smoking rates.
Hitt & Hendryx 2010 US	Retrospective analysis. The relationship between West Virginia SCI and cancer mortality rates from 1979-2005 was analysed.	West Virginian cancer mortality data from the CDC.	Cancer mortality rates. Ecological integrity (SCI). Coal mining intensity.	• Respiratory, digestive, urinary and breast cancer rates increased with ecological disintegrity, but genital and oral cancers did not. • Coal mining was significantly associated with ecological disintegrity and higher cancer mortality (p < 0.01). • Spatial analyses also indicated cancer clusters that corresponded to areas of high coal mining intensity (p < 0.01).	
Temple & Skyes 1992 UK	Cohort study. Medical records of new episodes of asthma were collated from before and after an open-cast coal mine began operating.	All patients presenting to the Glynneath Medical Practice, Wales.	Changes in the number of weekly episodes of asthma.	Before mining operations began the mean weekly number of new episodes of asthma was 4.4 (95% CI: 3.6-5.2) and after mining began it was 7.9 (95% CI: 7.0-8.6; p = < 0.001).	Data collection was blinded proving the results were not due to seasonal or other transient factors.

Author, year country	**Study type & method**	**Study population**	**Outcomes**	**Relevant results**	**Comments**
Veugelers & Guernsey 1999 Canada	Retrospective analysis. Annual disease-specific mortality counts by gender, age and geographic location from Statistics Canada from 1950-1995 were compared.	Cape Breton County, it's municipalities Glace Bay and Sydney, and Canada as a whole.	Life loss.	• Life expectancy in some municipalities of Cape Breton County was reduced by more than 5 years compared to the rest of Canada. • Life loss among Cape Breton County women was primarily attributable to cancer (life loss = 0.87 years) and among men to CVD (life loss = 1.25 years). • Life loss from cancer was higher in the steel-producing communities; whereas life loss from respiratory diseases and lung cancer was higher in the coal mining communities.	Extrapolating the trends in the most recent five decades, a further increase of the health deficiencies of Cape Breton County is anticipated.
Zullig & Hendryx 2010 US	Retrospective analysis. Telephone health surveys from the 2006 national BRFSS on HRQOL were compared between coal mining counties and other counties.	236,195 adults, aged ≥ 18 years. - Appalachian counties with coal mining (n = 9,339). - Appalachian counties with no coal mining (n = 9,626). - Non-Appalachian counties with coal mining (n = 9,092). - Other non-coal mining counties across the US (n = 208,138).	Self-rated HRQOL. - Number of poor physical days. - Number of poor mental days. - Activity limitation days.	• Residents of coal mining counties reported significantly fewer healthy days for both physical and mental health, and poorer self-rated health ($p < 0.0005$) when compared with referent non-coal mining counties (OR = 1.11, 95% CI: 1.05-1.18). • Disparities were greatest for people residing in Appalachian coal mining areas.	Results remained consistent in separate analyses by gender and age. Limitations included lack of accurate exposure data as county of residence is a crude measure of exposure.

Author, year country	**Study type & method**	**Study population**	**Outcomes**	**Relevant results**	**Comments**
Zullig & Hendryx 2011 US	Retrospective analysis. Telephone health surveys from the 2006 national BRFSS on HRQOL were compared between MTM areas, coal mining in non-MTM areas and non-mining areas.	10,234 adults, aged ≥ 18 years. - MTM areas (n = 19). - Coal mining in non-MTM areas (n = 23). - Non-coal mining areas (n = 78).	Self-rated HRQOL. - Number of poor physical days. - Number of poor mental days. - Activity limitation days. Healthy days index.	• Before and after adjusting for variables, residents of MTM counties reported significantly more days of poor physical, mental and activity limitation and poorer self-rated health ($p < 0.01$) compared with the other county groupings. • Residents in other mining counties had 1.30 greater odds of reporting fair or poor self-rated health (95% CI: 1.15-[-1.48]; $p < 0.001$) compared with non-coal mining counties. After adjusting for variables these differences were not significant.	Variables included metropolitan status, physician supply and BRFSS behavioural and demographic variables.

Table 2: Coal mining – children and infants

Author, year country	Study type & method	Study population	Outcomes	Relevant results	Comments
Ahern et al 2011a US	Retrospective analysis. National Center for Health Statistics natality files from 1996-2003 were used to analyse live births in MTM areas, coal mining in non-MTM areas and non-mining areas.	1,889,071 live birth health from residents of Kentucky, Tennessee, Virginia and West Virginia. - 109,315 from MTM areas. - 112,771 from mining in non-MTM areas. - 1,666,985 from non-mining areas.	Birth defects.	• The PRR for any birth defect was significantly higher in MTM areas compared to non-mining areas (PRR = 1.26, 95% CI: 1.21-1.32), but was not higher in the non-MTM areas, after controlling for covariates. • Rates were significantly higher in MTM areas for circulatory/respiratory, central nervous system, musculoskeletal, gastrointestinal and urogenital defects.	Covariates included mother's age, race, education, alcohol intake, smoking, diabetes, prenatal care and infants gender. Socioeconomic and environmental factors in MTM areas may be contributing factors.
Ahern et al 2011b US	Cross-sectional, retrospective analysis. The association between low birth weight and mother's residence in coal mining areas from 2005-2007.	42,770 live birth records from hospitals in West Virginia.	Low birth weight (< 2.5 kg). Coal mining areas and production.	• Residence in coal mining areas of West Virginia posed an independent risk of low birth weight. • Evidence of dose effective response for low birth rates in high coal mining (OR = 1.16, 95% CI: 1.08-1.25; p < 0.0002) and moderate coal mining (OR 1.14, 95% CI: 1.04-1.25; p < 0.003). • Adjusted findings show that living in areas with high levels of coal mining elevates the odds of a low birth weight infant by 16%, and by 14% in areas with lower mining levels, relative to counties with no coal mining.	Covariates included mothers' demographics, behaviors and insurance.

Author, year country	**Study type & method**	**Study population**	**Outcomes**	**Relevant results**	**Comments**
Brabin et al 1994 UK	Cross sectional survey. Health questionnaires completed parents and children in 1991-1993 were compared between school children exposed to different levels of steam coal dust.	1,872 children, aged 5-11 years old, from five primary schools in the Bootle dock area of Liverpool (exposed area), five primary schools in South Sefton (control area), and five primary schools in Wallasey (control area). Survey response rate: 92%	Respiratory symptoms (cough, wheezing, and shortness of breath), allergy and atopy. Air pollution levels.	• Respiratory symptoms were significantly more common in the exposed area children, including wheeze (25.0%, 20.6%, and 17.5%; p < 0.01), excess cough (40.0%, 23.4%, and 25.1%; p < 0.001), and school absences for respiratory symptoms (47.5%, 35.9%, and 34.9%; p < 0.001). • Differences remained significant after adjusting for parents smoking and employment status. • Multiple logistic regression analysis confirmed the exposed zone as a significant risk factor for absenteeism from school due to respiratory symptoms (OR = 1.55, 95% CI: 1.17-2.06) after adjusting for confounding factors.	Confounding factors included history of respiratory disease, existence of current respiratory illness and severity. Standard dust deposit gauges on three schools confirmed a significantly higher dust burden in the exposed zone.
Liao et al 2010 China	Retrospective analysis. Analysis of all live and still hospital births from 1998-2005 records in a coal mining area.	7,880 births in Heshun, Shanxi Province, China.	NTDs.	• The prevalence of NTDs in Heshun was 237.31 per 10,000 births (187/7880). • 58.3% of births with NTDs lived in the coal region. • Residing within 6 km of coal mining areas was associated with an increased risk of NTD (RR = 1.34, 95% CI: 1.00-1.78).	Individual exposure levels, home birth data were not available.

Author, year country	Study type & method	Study population	Outcomes	Relevant results	Comments
Pless-Mulloli et al 2000 UK	Matched pairs case control study. Health information was obtained from a postal questionnaire, a daily symptom diary and GP records, these were compared between communities at different proximities to an open-cast mine.	4,860 children, aged 1-11 years, in Northern England. - 2,443 from five communities close to open-cast coal mine. - 2,417 in from five communities away from active open-cast coal mine.	The cumulative and period prevalence (2 and 12 months) of wheeze, asthma, bronchitis and other respiratory symptoms. Prevalence and incidence of daily symptoms and GP consultations. Air pollution levels.	• Little evidence was found for associations between living near an open-cast site and an increased prevalence of respiratory illnesses, asthma severity, or daily diary symptoms. • Children in four of the five open-cast communities had significantly more respiratory consultations than control communities. (1.5 v 1.1 per person-year; OR = 1.42, 95% CI: 1.13-1.79). • Small but significant associations were found between daily respiratory symptoms and daily concentrations of PM. • Particulate matter levels were higher in open-cast areas: mean ratio 1.14, 95% CI: 1.13-1.16.	There was the level of variation between the communities and pairs, even though they were well matched for lifestyle and socioeconomic factors.
Pless-Mulloli et al 2001 UK	Matched pairs case control study. A health and lifestyle postal questionnaire between communities at different proximities to an open-cast mine.	4,860 children, aged 1-11 years, in Northern England. - 2,443 from five communities close to open-cast coal mine. - 2,417 in from five communities away from active open-cast coal mine.	The cumulative and period prevalence (2 and 12 months) of wheeze, asthma, bronchitis and other respiratory symptoms.	• The cumulative prevalence of wheeze was 36% in open-cast communities and 37% in the other communities. • The cumulative prevalence of asthma was 22% in both communities (range: 12-24%). • Little evidence for associations between living near an open-cast site and an increased prevalence of respiratory illnesses, or asthma severity. Some outcomes such as allergies, hayfever, or cough varied little across the study communities. Others, such as the use of asthma medication, the number of severe wheezing attacks in the past year or tonsillitis showed large variation.	The similarities and variations were not explained by differences in lifestyle factors or differences in health service delivery and remain unexplained.

Author, year country	Study type & method	Study population	Outcomes	Relevant results	Comments
Yapici et al 2006 Turkey	Cohort study. Blood was assessed for levels of lead and cadmium from children residing in a coal mining area.	236 children, aged 6 months-6 years old, from Yatagan, Turkey.	Lead and cadmium blood levels.	• 95.7% of children had a blood lead level of > 10ug/dL and 87.6% had > 20 microg/dL. • The blood cadmium level was above the risk limit of 0.5g/dL in 85% of the children. • Analysis showed a statistically significant negative correlation between blood lead levels and blood cadmium levels and age in both sexes (p < 0.001).	Asymptomatic lead poisoning was defined as > 10ug/dL. The risk limit for cadmium levels in the blood was accepted at 0.5g/dL.

Table 3: Power stations – adults (and whole population)

Author, year country	Study type & method	Study population	Outcomes	Relevant Results	Comments
Bencko et al 2009 Slovakia	Population-based survey. NMSC cases from 1977-1996 were collected from a town in close proximity to a power plant and compared to a control town.	Prievidza district, Solvakia. - Exposed group resided ≤ 7.5 km of the power plant. - Control group resided > 7.5 km away from the power plant.	NMSC cases. Arsenic content in hair and urine samples.	• During the 5 year period 1977-1981 there was a dramatic increment in the incidence of NMSC in the most polluted region of Prievidza district (RR = 2.05; p = 0.05). • This upward trend gradually reversed during the next 5 year periods following reduction in the arsenic emissions from the power plant.	
Boffetta et al 1991 Global	Literature review. Cohort studies on morbidity and mortality rates between groups of populations with different levels of environmental exposures were collated.	167 published epidemiological studies from 1965-1990 focusing on cancer risks related to fossil fuel-based industrial processes.	Cancer risks.	Air emissions from fossil-fuelled power plants represent one of the exposures of major concern for carcinogenicity of electricity production.	The review was completed by the International Agency for Research on Cancer, France.
Garcia-Perez et al 2009 Spain	Population-based study. Sex-specific standardised mortality ratios for lung, laryngeal and bladder tumors from 1994-2003 were calculated and an association with air pollution exposure was made.	8,073 Spanish towns included in the European Pollutant Emission Register. - < 5 km from a power plant. - ≤ 5 km from any industrial installation other than a power plant. - No industry within 5 km of residence.	Standardised mortality ratios s for lung, laryngeal and bladder tumors. Pollution exposure. Effect of type of fuel used.	• Excess mortality was detected in the vicinity of pre-1990 installations for lung cancer (RR = 1.07, 95% CI: 1.04-1.09) and laryngeal cancer among men (RR = 1.07, 95% CI: 0.99-1.15). • Lung cancer displayed excess mortality for all types of fuel used, whereas in laryngeal and bladder cancer, the excess was associated with coal-fired industries. • There was a risk gradient effect in the proximity of a number of installations.	

Author, year country	Study type & method	Study population	Outcomes	Relevant Results	Comments
Goren et al 1995 Israel	Cohort study. Yearly analyses of mortality rates, health services data and LFTs of individuals in communities located in close proximity to a coal-fired power plant from 1980-1990 were obtained.	30,000 adults and children, residing ≤ 10 km of a power plant in Israel.	Use of outpatient clinics. Air pollution levels.	• No consistent trend of change in the use of adult clinics due to respiratory tract complaints was observed between 1982-1990. • Air pollution levels measured were low and did not cause adverse health effects.	Ambient air pollution levels did not exceed the Israeli air quality standards. The survey results were not able to distinguish between acute and planned visits nor were able to identify multiple visits of the same patients which may have compromised results.
Karavus et al 2002 Turkey	Case control study. The effects of exposure to a coal-fired power plant on respiratory status using questionnaires, spirometric parameters and power plant ash in 1999 were calculated.	People > 15 years from villages in Kutahya Province, Turkey. - 277 residing ≤ 5 km from the power plant. - 225 residing > 30 km away from the power plant.	Respiratory complaints and spirometric parameters. Air pollution levels.	• Among people living in the villages around power plant, 46.2% had complaints of chest tightness ($p = 0.001$) and 29.2% repeated coughing attacks present for more than one year ($p = 0.024$). These percentages were 28.0% and 20.4% in the control villages respectively. • 50.7% of individuals in the exposure group aged 35-54 had significantly more complaints of chest tightness than the 21.3% of individuals from the control group aged 35-54 ($p = 0.0006$). • Mean spirometric parameters were significantly lower in individuals in the exposure group compared to the individuals in the control group ($p = 0.0001$). These measures were not statistically significant for current smokers ($p > 0.05$).	No individuals in the study worked at the power plant.
Pesch et al 2002 Slovakia	Case control study. Geographical and environmental data with medical records from 1996-1999 investigated the risk of arsenic exposure on NMSC development.	Prievidza, Slovakia. - 264 patients with a confirmed diagnosis of NMSC. - 286 individuals without NMSC.	Arsenic exposure assed by: - residential history. - annual power plant emissions. - nutritional habits.	• Age and gender adjusted risk estimates for NMSC in the highest exposure category (90th v 30th percentile) were (OR = 1.90, 95% CI: 1.39-2.60). • No interaction was found between arsenic exposure and dietary and residential data.	

Table 4: Power stations – children, infants, and fetal outcomes

Author, year country	Study type & method	Study population	Outcomes	Relevant Results	Comments
Aekplakorn et al 2003 Thailand	Observational study. The association between daily exposure to SO_2 and PM with pulmonary function was investigated.	175 children, aged 6-14 years, residing in 4 villages within ~7 km of a coal-fired power plant in Maemoh, Thailand. - 83 asthmatics. - 92 non-asthmatics.	Pulmonary function. Air pollution levels.	• In asthmatic children, a daily increase in SO_2 was associated with negligible declines in pulmonary function, but a small negative association was found between PM and pulmonary function. • No consistent associations between air pollution and pulmonary function were found for non-asthmatic children.	The 24 hour average PM and SO_2 levels were below Thai standards.
Dubnov et al 2007 Israel	Cohort studies. The association between children's lung function development and their long-term exposure to air pollution was collected and examined from two cohort studies conducted in 1996 and 1999.	1,492 children residing in two communities ≤ 10 km from a major coal-fired power plant in the Hadera district of Israel.	Pulmonary function. Air pollution levels.	Children exposed to higher levels of air pollution from the coal-fired power station were more likely to be hindered in their pulmonary growth ($p < 0.001$).	Results were controlled for road proximity, duration of residence in the area, housing density, father's education, gender, passive smoking and pulmonary diseases. Ambient air pollution levels did not exceed the Israeli air quality standards.
Goren & Hellmann, 1997 Israel	Cross sectional study. Long term study in three communities in Israel using health questionnaires, measuring lung function and health services data from 1980-1989.	School children in 2nd, 5th and 8th grade located within 19km of the power plant were followed up every 3 years. - 834 children in 1980. - 957 children in 1983. - 1,074 children in 1986. - 802 children in 1989.	Effects on asthma prevalence in school children living in proximity to a power plant station.	• A significant increase in the prevalence of asthma could be observed among 5th grade children in all three communities studied between 1980-1989 ($p = 0.002$). • There was also a significant rise in the prevalence of wheezing and shortness of breath ($p = 0.02$).	

Author, year country	**Study type & method**	**Study population**	**Outcomes**	**Relevant Results**	**Comments**
Halliday et al 1993 Australia	Cross sectional survey. The effect of residing in the proximity of power plants was measured using a questionnaire to parents as well as by lung function and bronchial hyperreactivity measurements.	851 children, aged 5-12 years, from Lake Munmorah, NSW (a town near two power stations) and Dungog, NSW (control town). Survey response rate: 92% in Lake Munmorah and 93% in Dungog.	Lung function (wheeze, bronchial hyperreactivity and symptoms of asthma).	• Current wheeze was reported in 24.8% of the Lake Munmorah children compared with 14.6% of the Dungog children. • Bronchial hyperreactivity was similar for both groups although baseline FEV was significantly lower in Lake Munmorah ($p < 0001$). • After adjusting for variables, the odds of current wheeze in Lake Munmorah compared with Dungog was 2.16 (95% CI: 1.45-3.15).	Variables included age, gender, passive smoking and dust mite allergy.
Henry et al 1991a Australia	Prevalence survey and longitudinal follow-up study. The effect of residing in the proximity of power plants was measured using a questionnaire to parents as well as lung function measurements. These were obtained at two intervals, 1 year apart.	602 children in the prevalence survey and 529 in the follow-up study from Lake Munmorah, NSW (a town near two power stations) and Nelson Bay, NSW (control town). Survey response rate: 76% and 91% in Lake Munmorah; and 70% and 86% in Nelson Bay.	Lung function (respiratory symptoms and bronchial reactivity).	• Prevalence of ever wheezed, current wheezing, breathlessness, wheezing with exercise, diagnosed asthma, and use of drugs for asthma at Lake Munmorah were all approximately double the prevalence at Nelson Bay (all p values < 0.01). • Prevalence of bronchial reactivity was only significantly greater ($p < 0.01$) in Lake Munmorah at the first but not the second survey.	Asthma was more common in the community near power stations than in the control area.
Henry et al 1991b Australia	Longitudinal study. The effect of living in the vicinity of coal-fired power stations on children with asthma was studied for 1 year, using daily diaries and measurements of air quality.	99 school children with a history of wheezing in the previous 12 months from Lake Munmorah, NSW (≤ 5 km of two power stations) and Nelson Bay, NSW (control town).	Respiratory symptoms and asthma treatment. Air pollution levels.	• Marked weekly fluctuations occurred in the prevalence of cough, wheezing, and breathlessness, without any substantial differences between the towns. • The overall prevalence of symptoms was low.	Measurements of SO_2 and NO_x at Lake Munmorah were well within recommended guidelines although they were several times higher than at Nelson Bay.

Author, year country	Study type & method	Study population	Outcomes	Relevant Results	Comments
Mohorovic 2004 Croatia	Retrospective analysis. Prenatal and birth data from 1987-1989 was obtained to examine the effect of coal power plant exposure and related SO_2 emissions in pregnant women.	704 pregnant women, in the vicinity of a coal power plant in Labin, Istra, Croatia.	Pregnancy complications and birth weight. Air pollution levels.	Greater and longer exposure to SO_2 emissions during the initial two months of pregnancy resulted in significantly shorter gestation ($p = 0.008$) and in lower birth weight infant ($p = 0.02$).	
Mohorovic et al 2010 Croatia	Cross control study. Prenatal exposure to products of coal combustion and complications in pregnancy were compared between two groups.	Pregnant women living near a power plant Istria, Croatia. - 122 during its operation. - 138 during the power plant closure.	Miscarriages, premature births and stillbirths.	Significant increase in still births in women living near the power plant during the time of its operation compared to the control group ($p = 0.02$).	
Peled et al 2005 Israel	Nested cohort study. Health questionnaires, PEF results and daily measurements of humidity and particulate matter were compared between communities living in close proximity to a power plant.	285 children, aged 10-12 years, with confirmed asthma from three communities living in close proximity to a power plant in Israel.	Lung function. Air pollution levels.	Exposure to air pollution with ultra fine particles was significantly associated with asthma attacks, increased use of asthma medications and decreased lung function in children with asthma ($p = 0.000$).	Results were controlled for temperature, barometric pressure, BMI, severity of asthma and socio-demographic parameters. Limitations included that the study did not cover all four seasons for each child and there was no data on parents smoking habits.
Perera et al 2008 China	Prospective cohort studies. The association between PAH exposure and neuro-developmental outcomes, measured by the Gesell Development schedules at 2 years of age, were compared between a cohort during the operation of the power plant and when it had shut down.	Non-smoking mother-child pairs residing ≤ 2 km of a coal-fired power plant in Tongliang, China. - Cohort 1: 150 pairs; 133 retained. - Cohort 2: 158 pairs; 122 retained.	PAH-DNA adducts from cord blood. DQs in motor, adaptive, language and social areas.	The significant associations between elevated PAH's in umbilical cord blood and decreased motor area DQ ($p = 0.04$) and average DQ ($p = 0.04$) seen at 2 years of age in the first cohort were not observed in the second cohort study ($p = 0.56$ and $p = 0.15$), which was conducted post mine shutdown.	

Author, year country	**Study type & method**	**Study population**	**Outcomes**	**Relevant Results**	**Comments**
Tang 2006 China	Cohort study. The relationship between prenatal exposure to PAH on fetal and child growth and development was examined.	150 non-smoking women and their newborns, residing ≤ 2.5 km of a coal-fired power plant in Tongliang, China.	PHA-DNA adducts from maternal and umbilical cord blood. Fetal and child growth and development measures.	• Prenatal exposure to elevated levels of PAH was associated with decreased birth head circumference ($p = 0.057$) and reduced child's weight at 18 ($p = 0.03$), 24 ($p = 0.03$) and 30 months of age ($p < 0.05$). • Longer duration of prenatal exposure was associated with reduced birth length ($p = 0.03$) and reduced children's height at 18 ($p = 0.001$), 24 ($p < 0.001$) and 30 months of age ($p < 0.001$).	
Tang et al 2008 China	Cohort study. The association between prenatal PAH exposure, measured in umbilical cord blood, and neurodevelopmental outcomes, measured by the Gesell Development schedules at 2 years of age.	150 non-smoking women and their newborns, residing ≤ 2.5 km of a coal-fired power plant in Tongliang, China.	PAH-DNA adducts. Lead and mercury in umbilical cord blood. DQs in motor, adaptive, language and social areas.	• Decrements in one or more DQs were significantly associated with cord blood levels of PAH-DNA adduct and lead, but not mercury. • Increased adduct levels were associated with decreased motor area DQ ($p = 0.04$), language area DQ ($p = 0.059$), and average DQ ($p = 0.05$) after adjusting for confounders. • High cord blood lead level was significantly associated with decreased social area DQ ($p = 0.009$) and average DQ ($p = 0.04$).	

Author, year country	Study type & method	Study population	Outcomes	Relevant Results	Comments
Wong et al 2005 Taiwan	Cross-sectional study. The association between internal concentrations of arsenic, chromium and nickel and the level of oxidative stress to DNA from a power plant was investigated.	142 children, aged 10-12 years, attending three elementary schools in Taichung county, Taiwan. - 49 from Longgang school, adjacent to the Taichung power plant. - 45 from Shalach school (control). - 48 from Shuntain school (control).	Urinary levels of arsenic, chromium and nickel. 8-OHdG levels.	• No obvious relationship between the levels of urinary nickel and 8-OHdG was found. • Multiple linear regression analysis showed that children with higher urinary chromium had greater urinary 8-OHdG than did those with lower urinary chromium. • Subjects with higher urinary arsenic had greater urinary 8-OHdG than did those with lower urinary arsenic. • Children with high urinary arsenic and chromium levels had the highest 8-OHdG levels vs. low arsenic/low chromium ($p < 0.01$); followed by low arsenic/high chromium, high arsenic/low chromium and low arsenic/low chromium; the trend was significant ($p < 0.001$).	
Yogev-Baggio et al 2010 Israel	Prospective cohort Study. The effect of exposure to air pollution on the development of pulmonary function was evaluated between children characterised by different respiratory health status.	1,181 school children, residing near a major coal-fired power plant in the Hadera district of Israel. - Healthy children. - Children experiencing chest symptoms. - Children with asthma or spastic bronchitis.	Pulmonary function tests. Air pollution levels.	• When controlling for cofounders, a significant negative association was found between changes in PFT results and individual exposure estimates to air pollution ($p < 0.01$). • Long-term exposure to ambient air pollution has more detrimental effects on pulmonary function growth among children with chest symptoms and healthy children than among asthmatics.	Results controlled for height, age, gender, parental education, passive smoking and residential status.

Abbreviations: 8-OHdG 8-hydroxy-2-deoxyguanosine, BMI body mass index, BRFSS Behavioural Risk Factor Surveillance System, CDC Centers of Disease Control, CHD coronary heart disease, CI confidence interval, COPD chronic obstructive pulmonary disease, CVD cardiovascular disease, DQ developmental quotient, FEV forced expiratory volume, GIS Geographic Information System, GP general practitioner, HRQOL health related quality of life, LFT lung function test, MTM mountain top mining, NMSC non-melanoma skin cancer, NO_x nitrogen oxides, NTD neural tube defect, OR odds ratio, PAH polycyclic aromatic hydrocarbons, PAH-DNA polycyclic aromatic hydrocarbon-deoxyribonucleic acid, PEF peak expiratory flow, PM particle matter, PRR prevalence rate ratio, RR relative risk, SCI Stream Condition Index, SO_2 sulphur dioxide, UK United Kingdom, US united States, VSL value of statistical life lost.

APPENDIX B

EVIDENCE TABLES FOR RESEARCH QUESTION 3

Are there clusters of these diseases or other health problems in the Hunter Region of New South Wales

Appendix B: Summary of Evidence for Research Question 3

Author, year country	Study type & method	Study population	Outcomes	Relevant Results	Comments
Blakeney & Marshall 2009 US	Cross sectional study. Three phase study investigating water quality. Surveyed health professionals and community members in Letcher county, Eastern Kentucky.	40 adults aged ≥ 18 years living in Letcher county. - 23 men. - 17 women.	Association between water quality, health and human occupations.	• The watershed in Letcher county, Kentucky is polluted as a result of specific coal mining practices and a lack of adequate infrastructure. • Citizens experience occupational injustice in the form of occupational imbalance, occupational deprivation and occupational alienation.	
Lockie et al 2009 Australia	Social impact assessment. Semi-structured interviews of stakeholders to scope potential impacts of mine, and a desktop study to identify further potential impacts. Two phase study in 2002-2003 and 2006-2007. Baseline assessment of impacts and mitigation strategies through community interviews, analysis from data provided from other agencies, and short quantitative surveys.	'Stakeholders' i.e. those who were affected by or involved in the Coppabella coal mine, QLD: - community. - representatives. - local businesses. - mine workers. - residents of Nebo.	Social impacts of the Coppabella coal mine.	• While mining was only responsible for a small increase in population, demographic and social changes undermined the likely ability of the community to generate alternative economic and cultural futures. • Other social impacts from mining included: severe shortages of skilled labour in other industries, reduced accommodation access and affordability, an increase in traffic and fatigue related road accidents, increased pressure on emergency services and increases in criminal and anti-social behaviour.	Research was funded by Macarthur Coal. Social impact assessments were conducted outside Queensland's legislative framework to tailor the assessments to focus on cumulative impacts.

Author, year country	**Study type & method**	**Study population**	**Outcomes**	**Relevant Results**	**Comments**
Moffatt & Pless-Mulloli 2003 UK	Retrospective study. Face to face interviews on health and the environment with parents living in four communities < 750 m away from an open-cast coal mine in North East England. Taken in tandem with an epidemiological investigation to establish if open-cast mining adversely affects children's respiratory health.	Total of 31 interviews of parents living in one of 4 communities chosen: - 28 mothers only. - 2 fathers only. - 1 both parents.	Parents perceptions of the health and environmental impact of open-cast mining.	• 23 participants were of the view that there was an increase in asthma levels among children citing traffic pollution and open-cast mining as causes. • The epidemiological findings showed no increase in asthma prevalence but higher rates of GP consultations for respiratory conditions.	Scepticism and distrust of official sources of information was a common feature.
Pless-Mulloli et al 2000 UK	Matched pairs case control study. Health information was obtained from a postal questionnaire, a daily symptom diary and GP records, these were compared between communities at different proximities to an open-cast mine.	4,860 children, aged 1-11 years, in Northern England. - 2,443 from five communities close to open-cast coal mine. - 2,417 in from five communities away from active open-cast coal mine.	The cumulative and period prevalence (2 and 12 months) of wheeze, asthma, bronchitis and other respiratory symptoms. Prevalence and incidence of daily symptoms and GP consultations. Air pollution levels.	• Little evidence was found for associations between living near an open-cast site and an increased prevalence of respiratory illnesses, asthma severity, or daily diary symptoms. • Children in four of the five open-cast communities had significantly more respiratory consultations than control communities. (1.5 v 1.1 per person-year; OR = 1.42, 95% CI: 1.13-1.79). • Small but significant associations were found between daily respiratory symptoms and daily concentrations of PM. • Particulate matter levels were higher in open-cast areas: mean ratio 1.14, 95% CI: 1.13-1.16.	There was the level of variation between the communities and pairs, even though they were well matched for lifestyle and socioeconomic factors.

Author, year country	**Study type & method**	**Study population**	**Outcomes**	**Relevant Results**	**Comments**
Riva et al 2011 UK	Cross sectional study. Health surveys and geographical data were studied from 2004-2006 from the North East, West Midlands and South West of England.	Total of 26,097 adults aged > 18 years. - 4,733 lived in a former coalfield area.	Variation in health across former coalfield areas in England.	• Living in coalfields areas was significantly associated with a greater luikelihood of reporting a limited long term illness (OR = 1.39, 95% CI: 1.25-1.55) and less than good health (OR = 1.24, 95% CI: 1.12-1.37). • Women were significantly less likely than men to report a limited long term illness and less than good health, but more likely to report common mental health problems.	
Walker et al 2006 Russia	Cross sectional survey. Compared different social perceptions of environmental degradation through face to face interviews and environmental impact studies in the coal mining areas of Usinsk and Vorkuta in the sub-arctic region of Russia from 1998-2000.	Total of 175 individuals aged > 18 years. - 89 living in Usinsk. - 86 living in Vorkuta.	Levels of environmental pollution in the sub-arctic lowlands of north east European Russia.	• Environmental issues were a low priority among the people of Usinsk and Vorkuta, compared with other social problems. • People were concerned with the quality of their drinking water and with recreational activities such as swimming and fishing.	Human and ecologic impacts of environmental change are not so much about mean changes but rather about extreme events. An extreme event poses a risk because people have to respond quickly.

Abbreviations: CI confidence interval, GP general practitioner, OR odds ratio, QLD Queensland, UK United Kingdom, US united States.

APPENDIX C

EVIDENCE TABLES FOR RESEARCH QUESTION 4

Is there an association between coal mining and social injustice in the Hunter Region of NSW?

Appendix C: Summary of Evidence for Research Question 4

Author, year country	**Study type & method**	**Study population**	**Outcomes**	**Relevant Results**	**Comments**
Brereton et al 2008 Australia	Cross sectional study. Face to face interviews, four focus group sessions and a literature review to determine the cumulative impacts of mining on the local community.	Total of 53 adults aged > 18 years in Muswellbrook, NSW. - 19 interviewed. - 34 in focus groups.	Impacts of mining on regional communities. Framework for coal mining operations to monitor and manage cumulative impacts of mining.	• Broad agreement that mining had contributed significantly to economic development in Muswellbrook. • Majority agreement that pollution has a negative impact on the lives of local people e.g. visual and social impacts of mining.	
Connor et al 2004 Australia	Cross sectional survey. Perceptions of environmental change were investigated using interviews with key stakeholders, and in-depth semi-structured interviews with community residents.	Total of 55 people interviewed from the Upper Hunter Valley, NSW. - 13 key stakeholders. - 42 community residents.	Environmental change and the effect on human health.	Environmental change in the Upper Hunter is associated with considerable depth of feeling of personal distress about loss of, or damages to homes, farming properties, the landscape and community heritage.	Restructuring of rural industries and the decline of small farms was also a cause of distress to residents.
Connor et al 2008 Australia	Case study. The conflict over water during the Bickham coalmine proposal was investigated by analysing discourse.	Stakeholders of the Bickham coal mine, Upper Hunter Valley, NSW.	Asymmetry of power and control over water.	• The contestation over water was increasing due its increasing scarcity and the conflicting demands of local communities and the mining industry. • Policy changes to water rights reflected the advantage of political capital that the coal mining industry ha over local communities. • Inequalities in water rights and forced changes to the environment are issues of social injustice.	
Connor et al 2009 Australia	Case study. Changing opposition practices of the local communities near the Anvil Hill mine site were investigated using available literature.	Local communities affected by the Anvil Hill open-cut mine, Wybong area, Upper Hunter Region, NSW.	Oppositional practices of local communities. Environmental knowledge.	• The incorporation of global issues such as climate change has aided local communities in their opposition of coal mining projects. • Local communities face barriers to accessing information, such as 'gag clauses' in settlements, causing social divisions. • The mining industry has greater political privileges compared to local communities.	

Author, year country	Study type & method	Study population	Outcomes	Relevant Results	Comments
Dalton 2003 Australia	Cross sectional survey. Environmental health issues were identified using surveys of residents, government council members and Hunter Health Council members.	894 people > 15 years residing in the Hunter Valley, NSW. - 11 local government members. - 719 local residents. - 164 Hunter Health Council members.	Environmental health concerns in the Hunter Valley.	• 88% of respondents named air pollution as an environmental health concern followed by water pollution. • There were no differences by gender.	There was a trend for respondents of higher socioeconomic status (by postcode SEIFA) score to name an environmental concern compared to those of lower status.
Harris et al 2009 Australia	Qualitative descriptive analysis. Environmental impact assessments were analysed by developing an audit tool that then was applied to a stratified randomised sample.	22 environmental impact assessment reports from July 2006 to December 2007, taken from the NSW Department of Planning.	Inclusion of health in environmental impact assessments.	Health and well-being impacts are not considered explicitly in environmental impact assessments within major environmental projects in NSW. This is despite the likelihood of a range of health impacts occurring due to size and nature of the developments.	Small sample size meant descriptive statistics were unable to be used.
Higginbotham et al 2007 Australia	Cross sectional survey. Fieldwork was used to validate an EDS which was then used to analyse results of postal surveys.	203 residents of Singleton (high disturbance area from mining) and Dungog (low disturbance area from mining) in the Upper Hunter, NSW.	Validation of EDS. Environmental distress relative to location of coal mines.	• The EDS was validated, subscales were intercorrelated (r = 0.67-0.73) and had internal consistency reliability (Cronbach's alpha = 0.79-0.96) and test-retest reliability (ICC = 0.67-0.73). • Communities affected by mining have higher levels of environmental distress than communities not affected by mining.	
Higginbotham et al 2010 Australia	Literature review. Available literature was reviewed to determine environmental injustices in local communities caused by coal mining.	Hunter Valley, NSW.	Environmental injustice and air pollution in local communities.	• Coal mining is associated with intergenerational injustices through health inequity and environmental injustice. • Coal mining has dramatically changed the local environment. • Technical and methodological barriers are used by relevant authorities to prevent conducting a cumulative health study on the local populations.	

Author, year country	Study type & method	Study population	Outcomes	Relevant Results	Comments
Richardson & Denniss 2011 Australia	Literature review. Effects of the commodities boom in Australia were reviewed using available literature and data.	Australia	Social and economic effects of the mining industry in Australia.	• The government spends $10 billion annually in subsidies to support fossil fuel extraction. • The mining industry contributes 9% of Australia's total GDP. • State governments provide assistance to the mining industry through the Productivity Commission in many ways, e.g. through the provision of cheap water and power.	

Abbreviations: EDS environmental distress scale, GDP gross domestic product, ICC intraclass correlation coefficient, NSW New South Wales, SEIFA socio-economic indexes for areas

Media Release 16.10.12

The End of Camberwell: Rivers SOS visits Ms Wendy Bowman

Wendy Bowman of Camberwell (just north of Singleton) is the patron of the Rivers SOS Alliance, widely known in NSW for her resistance to mine damage to water sources and prime agricultural land, and as the founder of Hunter Minewatch. We visited her, and took the attached photos, shortly after the NSW Planning Commission (PAC) announced its approval, on Monday 8 October, of the expansion of Ashton Coal's mining operations in Camberwell. Camberwell, founded in 1820, is one of the oldest villages in the Hunter, with its original church still standing. But it is a dying community.

This mine expansion, called the South East Open Cut Project, will take mining operations right up to WendyBowman's door and destroy her lush lucerne paddocks on the alluvial flats beside Glennies Creek (see her cattle grazing by the creek in the photo on right)).

In total, half the alluvial flats will be mined and this will breach and dissect the shallow aquifers feeding the creek; which in turn supply Glennies Creek Dam (also known as Lake St Clair), which together with the Glenbawm Dam provides water for Singleton and the vineyards of Pokolbin and Broke, plus farms and villages downstream to the tidal pools at Maitland, via pipelines from the Hunter.

Excessive amounts of water are now extracted from Glenbawm Dam for Bayswater power station, so Glennies Creek is the major source for all users downstream.

The mine expansion will provide only 165 jobs, and only for seven years, yet the water supply will be permanently depleted and polluted.

The vineyards and the many plush tourist establishments around Pokolbin provide thousands of permanent and sustainable jobs; this is the second biggest tourism industry in NSW after Sydney itself. It is insane to deplete and pollute the water supply for this industry, as well as for the vineyards and other productive agricultural land.

There are many local farms which will be affected. Wendy Bowman was quoted in a local journal earlier this year, saying of her own 150 hectare property "Rosedale" that it is a "great little farm" beside Glennies Creek, where alluvial lucerne flats are complemented by flood-free grazing hills.

"Agriculture is our future," she said, "and farms like this with a guaranteed water supply are the future of agriculture - we could do so much to feed the world if the industry was not being destroyed by the mining juggernaut." There were five dairies in the Camberwell area when Wendy first came to live there, now there are none.

Seven years ago, her family farm "Granbalang" was resumed by the Rix's Creek coal mine and the heritage homestead was demolished; this is now the fate of her new home and garden, which Ashton Coal will certainly demolish (see "Rosedale" homestead in the second photo).

The project was opposed by the Newcastle branch of the NSW Office of Water but objections were later overruled by the head office in Parramatta, headed by one David Harris. Even the PAC panel was puzzled by what they called this “complete reversal of opposition .... a vexed issue ....given that there remained strongly divided opinions ... on the risks posed by the project." But PAC went ahead and approved it anyway, despite these misgivings.

The Department of Planning had recommended that the project be approved back in August 2011 but had met with stiff opposition from the Office of Water and from the Department of Health. So PAC rejected it in December 2011. However this was appealed successfully in the Land and Environment Court, then the Office of Water conveniently reversed its position in June 2012, and PAC had to make a new determination, in the end giving Ashton Coal the green light.

The whole process smacks of political pressure if not corruption. Mining companies can keep on appealing till they get their way, whatever the risk to other industries relying on water resources.

This PAC panel consisted of only two members: Gabrielle Kibble and Neil Shepherd. Neither are environmental scientists, which might explain their willingness to ignore the precautionary principle. But why would they override water and health concerns and reverse PAC's own previous position?

Wendy Bowman thinks that, as the Chinese company Yanco has a large stake in Ashton Coal, the decision may have been in China's favour for political reasons.

Bev Smiles, of the Hunter Communities Network, commented in today's Newcastle Herald that “the independence of PAC can be viewed as severely compromised in this process."

The expansion was always opposed by local health officials; and at least their position has not changed. In an area already surrounded by mines, Dr Au of Singleton has found that 20% of local children aged 8 - 11 have respiratory problems, but he has been told to stop carrying out lung function tests in primary schools because this "might worry the children and parents". Some parents Wendy knows take their children away for weekends as often as possible, to relieve symptoms of asthma.

The Upper Hunter Air Quality Monitoring Network has sent out 16 health alerts in Camberwell from August this year. Dust levels have exceeded national standards. The new open cut operation will of course worsen this appalling state of affairs.

Wendy Bowman says that, having held out for many years, she will now have to move once again as she could not face an open cut mine at her front door. Already, as she showed us, there is thick fine coal dust from nearby mines on the inside of windows in her locked living room, and her lungs are affected (see Wendy in her living room in the first photo).

Once again, reckless and irresponsible mining approvals are wrecking people's health, lives and industries for short term profits.

Our sympathy goes out to people like Wendy Bowman in her sad predicament. There are countless people in this position but her case, as our patron, is very special for us.

There is some possibility of an appeal; and we can only hope that the Environmental Defenders Office is not going to be dismantled by the O'Farrell government, as has been rumoured.

Wendy Bowman is happy to be interviewed. Her phone numbers are 0427400837 or 65761957.

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Full cost accounting for the life cycle of coal

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Each stage in the life cycle of coal—extraction, transport, processing, and combustion—generates a waste stream and carries multiple hazards for health and the environment. These costs are external to the coal industry and are thus often considered "externalities." We estimate that the life cycle effects of coal and the waste stream generated are costing the U.S. public a third to over one-half of a trillion dollars annually. Many of these so-called externalities are, moreover, cumulative. Accounting for the damages conservatively doubles to triples the price of electricity from coal per kWh generated, making wind, solar, and other forms of nonfossil fuel power generation, along with investments in efficiency and electricity conservation methods, economically competitive. We focus on Appalachia, though coal is mined in other regions of the United States and is burned throughout the world.

Keywords: coal; environmental impacts; human and wildlife health consequences; carbon capture and storage; climate change

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Introduction

Coal is currently the predominant fuel for electricity generation worldwide. In 2005, coal use generated 7,334 TWh (1 terawatt hour = 1 trillion watt-hours, a measure of power) of electricity, which was then 40% of all electricity worldwide. In 2005, coal-derived electricity was responsible for 7.856 Gt of CO_2 emissions or 30% of all worldwide carbon dioxide (CO_2) emissions, and 72% of CO_2 emissions from power generation (one gigaton = one billion tons; one metric ton = 2,204 pounds.)[1] Non–power-generation uses of coal, including industry (e.g., steel, glass-blowing), transport, residential services, and agriculture, were responsible for another 3.124 Gt of CO_2, bringing coal's total burden of CO_2 emissions to 41% of worldwide CO_2 emissions in 2005.[1]

By 2030, electricity demand worldwide is projected to double (from a 2005 baseline) to 35,384 TWh, an annual increase of 2.7%, with the quantity of electricity generated from coal growing 3.1% per annum to 15,796 TWh.[1] In this same time period, worldwide CO_2 emissions are projected to grow 1.8% per year, to 41.905 Gt, with emissions from the coal-power electricity sector projected to grow 2.3% per year to 13.884 Gt.[1]

In the United States, coal has produced approximately half of the nation's electricity since 1995,[2] and demand for electricity in the United States is projected to grow 1.3% per year from 2005 to 2030, to 5,947 TWh.[1] In this same time period, coal-derived electricity is projected to grow 1.5% per year to 3,148 TWh (assuming no policy changes from the present).[1] Other agencies show similar projections; the U.S. Energy Information Administration (EIA)

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projects that U.S. demand for coal power will grow from 1,934 TWh in 2006 to 2,334 TWh in 2030, or 0.8% growth per year.[3]

To address the impact of coal on the global climate, carbon capture and storage (CCS) has been proposed. The costs of plant construction and the "energy penalty" from CCS, whereby 25–40% more coal would be needed to produce the same amount of energy, would increase the amount of coal mined, transported, processed, and combusted, as well as the waste generated, to produce the same amount of electricity.[1,4] Construction costs, compression, liquefaction and injection technology, new infrastructure, and the energy penalty would nearly double the costs of electricity generation from coal plants using current combustion technology (see Table 2).[5]

Adequate energy planning requires an accurate assessment of coal reserves. The total recoverable reserves of coal worldwide have been estimated to be approximately 929 billion short tons (one short ton = 2,000 pounds).[2] Two-thirds of this is found in four countries: U.S. 28%; Russia 19%; China 14%, and India 7%.[6] In the United States, coal is mined in 25 states.[2] Much of the new mining in Appalachia is projected to come from mountaintop removal (MTR).[2]

Box 1.

Peak Coal?

With 268 billion tons of estimated recoverable reserves (ERR) reported by the U.S. Energy Information Administration (EIA), it is often estimated that the United States has "200 years of coal" supply.[7] However, the EIA has acknowledged that what the EIA terms ERR cannot technically be called "reserves" because they have not been analyzed for profitability of extraction.[7] As a result, the oft-repeated claim of a "200 year supply" of U.S. coal does not appear to be grounded on thorough analysis of economically recoverable coal supplies.

Reviews of existing coal mine lifespan and economic recoverability reveal serious constraints on existing coal production and numerous constraints facing future coal mine expansion. Depending on the resolution of the geologic, economic, legal, and transportation constraints facing future coal mine expansion, the planning horizon for moving beyond coal may be as short as 20–30 years.[8–11]

Recent multi-Hubbert cycle analysis estimates global peak coal production for 2011 and U.S. peak coal production for 2015.[12] The potential of "peak coal" thus raises questions for investments in coal-fired plants and CCS.

Worldwide, China is the chief consumer of coal, burning more than the United States, the European Union, and Japan combined. With worldwide demand for electricity, and oil and natural gas insecurities growing, the price of coal on global markets doubled from March 2007 to March 2008: from \$41 to \$85 per ton.[13] In 2010, it remained in the \$70+/ton range.

Coal burning produces one and a half times the CO_2 emissions of oil combustion and twice that from burning natural gas (for an equal amount of energy produced). The process of converting coal-to-liquid (not addressed in this study) and burning that liquid fuel produces especially high levels of CO_2 emissions.[13] The waste of energy due to inefficiencies is also enormous. Energy specialist Amory Lovins estimates that after mining, processing, transporting and burning coal, and transmitting the electricity, only about 3% of the energy in the coal is used in incandescent light bulbs.[14]

Thus, in the United States in 2005, coal produced 50% of the nation's electricity but 81% of the CO_2 emissions.[1] For 2030, coal is projected to produce 53% of U.S. power and 85% of the U.S. CO_2 emissions from electricity generation. None of these figures includes the additional life cycle greenhouse gas (GHG) emissions from coal, including methane from coal mines, emissions from coal transport, other GHG emissions (e.g., particulates or black carbon), and carbon and nitrous oxide (N_2O) emissions from land transformation in the case of MTR coal mining.

Coal mining and combustion releases many more chemicals than those responsible for climate forcing. Coal also contains mercury, lead, cadmium, arsenic, manganese, beryllium, chromium, and other toxic, and carcinogenic substances. Coal crushing, processing, and washing releases tons of particulate matter and chemicals on an annual basis and contaminates water, harming community public health and ecological systems.[15–19] Coal combustion also results in emissions of NO_x, sulfur dioxide (SO_2), the particulates PM_{10} and $PM_{2.5}$, and mercury; all of which negatively affect air quality and public health.[20–23]

In addition, 70% of rail traffic in the United States is dedicated to shipping coal, and rail transport is associated with accidents and deaths.[20] If coal use were to be expanded, land and transport infrastructure would be further stressed.

Summary of methods

Life cycle analysis, examining all stages in using a resource, is central to the full cost accounting needed to guide public policy and private investment. A previous study examined the life cycle stages of oil, but without systematic quantification.[24] This paper is intended to advance understanding of the measurable, quantifiable, and qualitative costs of coal.

In order to rigorously examine these different damage endpoints, we examined the many stages in the life cycle of coal, using a framework of environmental externalities, or "hidden costs." Externalities occur when the activity of one agent affects the well-being of another agent outside of any type of market mechanism—these are often not taken into account in decision making and when they are not accounted for, they can distort the decision-making process and reduce the welfare of society.[20] This work strives to derive monetary values for these externalities so that they can be used to inform policy making.

This paper tabulates a wide range of costs associated with the full life cycle of coal, separating those that are quantifiable and monetizable; those that are quantifiable, but difficult to monetize; and those that are qualitative.

A literature review was conducted to consolidate all impacts of coal-generated electricity over its life cycle, monetize and tabulate those that are monetizable, quantify those that are quantifiable, and describe the qualitative impacts. Since there is some uncertainty in the monetization of the damages, low, best, and high estimates are presented. The monetizable impacts found are damages due to climate change; public health damages from NO_x, SO_2, $PM_{2.5}$, and mercury emissions; fatalities of members of the public due to rail accidents during coal transport; the public health burden in Appalachia associated with coal mining; government subsidies; and lost value of abandoned mine lands. All values are presented in 2008 US$. Much of the research we draw upon represented uncertainty by presenting low and/or high estimates in addition to best estimates. Low and high values can indicate both uncertainty in parameters and different assumptions about the parameters that others used to calculate their estimates. Best estimates are not weighted averages, and are derived differently for each category, as explained below.

Climate impacts were monetized using estimates of the social cost of carbon—the valuation of the damages due to emissions of one metric ton of carbon, of \$30/ton of CO_2equivalent (CO_2e),[20] with low and high estimates of \$10/ton and \$100/ton. There is uncertainty around the total cost of climate change and its present value, thus uncertainty concerning the social cost of carbon derived from the total costs. To test for sensitivity to the assumptions about the total costs, low and high estimates of the social cost of carbon were used to produce low and high estimates for climate damage, as was done in the 2009 National Research Council (NRC) report on the "Hidden Costs of Energy."[20] To be consistent with the NRC report, this work uses a low value of \$10/ton CO_2e and a high value of \$100/ton CO_2e.

All public health impacts due to mortality were valued using the value of statistical life (VSL). The value most commonly used by the U.S. Environmental Protection Agency (EPA), and used in this paper, is the central estimate of \$6 million 2000 US\$, or \$7.5 million in 2008 US\$.[20]

Two values for mortality risk from exposure to air pollutants were found and differed due to different concentration-response functions—increases in mortality risk associated with exposure to air pollutants. The values derived using the lower of the two concentration-response functions is our low estimate, and the higher of the two concentration-response functions is our best and high estimate, for reasons explained below. The impacts on cognitive development and cardiovascular disease due to mercury exposure provided low, best, and high estimates, and these are presented here.

Regarding federal subsidies, two different estimates were found. To provide a conservative best estimate, the lower of the two values represents our low and best estimate, and the higher represents our high estimate. For the remaining costs, one point estimate was found in each instance, representing our low, best, and high estimates.

The monetizable impacts were normalized to per kWh of electricity produced, based on EIA estimates of electricity produced from coal, as was done in the NRC report tabulating externalities due to coal.[2,20] Some values were for all coal mining, not just for the portion emitted due to coal-derived electricity. To correct for this, the derived values were multiplied by the proportion of coal that was used for electrical power, which was approximately 90% in all years analyzed. The additional impacts from nonpower uses of coal, however, are not included in this analysis but do add to the assessment of the complete costs of coal.

To validate the findings, a life cycle assessment of coal-derived electricity was also performed using the Ecoinvent database in SimaPro v 7.1.[25] Health-related impact pathways were monetized using the value of disability-adjusted life-years from ExternE,[26] and the social costs of carbon.[20] Due to data limitations, this method could only be used to validate damages due to a subset of endpoints.

Box 2.

Summary Stats

1. Coal accounted for 25% of global energy consumption in 2005, but generated 41% of the CO_2 emissions that year.
2. In the United States, coal produces just over 50% of the electricity, but generates over 80% of the CO_2 emissions from the utility sector.[2]
3. Coal burning produces one and a half times more CO_2 emissions than does burning oil and twice that from burning natural gas (to produce an equal amount of energy).
4. The energy penalty from CCS (25–40%) would increase the amount of coal mined, transported, processed, and combusted, and the waste generated.[4]
5. Today, 70% of rail traffic in the United States is dedicated to shipping coal.[20] Land and transport would be further stressed with greater dependence on coal.

Life cycle impacts of coal

The health and environmental hazards associated with coal stem from extraction, processing, transportation and combustion of coal; the aerosolized, solid, and liquid waste stream associated with mining, processing, and combustion; and the health, environmental, and economic impacts of climate change (Table 1).

Underground mining and occupational health

The U.S. Mine Safety and Health Administration (MSHA) and the National Institute for Occupational Safety and Health (NIOSH) track occupational injuries and disabilities, chronic illnesses, and mortality in miners in the United States. From 1973 to 2006 the incidence rate of all nonfatal injuries decreased from 1973 to 1987, then increased dramatically in 1988, then decreased from 1988 to 2006.[27] Major accidents still occur. In January 2006, 17 miners died in Appalachian coal mines, including 12 at the Sago mine in West Virginia, and 29 miners died at the Upper Big Branch Mine in West VA on April 5, 2010. Since 1900 over 100,000 have been killed in coal mining accidents in the United States.[14]

In China, underground mining accidents cause 3,800–6,000 deaths annually,[28] though the number of mining-related deaths has decreased by half over the past decade. In 2009, 2,631 coal miners were killed by gas leaks, explosions, or flooded tunnels, according to the Chinese State Administration of Work Safety.[29]

Black lung disease (or pneumoconiosis), leading to chronic obstructive pulmonary disease, is the primary illness in underground coal miners. In the 1990s, over 10,000 former U.S. miners died from coal workers' pneumoconiosis and the prevalence has more than doubled since 1995.[30] Since 1900 coal workers' pneumoconiosis has killed over 200,000 in the United States.[14] These deaths and illnesses are reflected in wages and workers' comp, costs considered internal to the coal industry, but long-term support often depends on state and federal funds.

Again, the use of "coking" coal used in industry is also omitted from this analysis: a study performed in Pittsburgh demonstrated that rates of lung cancer for those working on a coke oven went up two and one-half times, and those working on the top level had the highest (10-fold) risk.[31]

Mountaintop removal

MTR is widespread in eastern Kentucky, West Virginia, and southwestern Virginia. To expose coal seams, mining companies remove forests and fragment rock with explosives. The rubble or "spoil" then sits precariously along edges and is dumped in the valleys below. MTR has been completed on approximately 500 sites in Kentucky, Virginia, West Virginia, and Tennessee,[32] completely altering some 1.4 million acres, burying 2,000 miles of streams.[33] In Kentucky, alone, there are 293 MTR sites, over 1,400 miles of streams damaged or destroyed, and 2,500 miles of streams polluted.[34–36] Valley fill and other surface mining practices associated with MTR bury headwater streams and contaminate surface and groundwater with carcinogens and heavy metals[16] and are associated with reports of cancer clusters,[37] a finding that requires further study.

The deforestation and landscape changes associated with MTR have impacts on carbon storage and water cycles. Life cycle GHG emissions from coal increase by up to 17% when those from deforestation and land transformation by MTR are included.[38] Fox and Campbell estimated the resulting emissions of GHGs due to land use changes in the Southern Appalachian Forest, which encompasses areas of southern West Virginia, eastern Kentucky, southwestern Virginia, and portions of eastern Tennessee, from a baseline of existing forestland.[38] They estimated that each year, between 6 and 6.9 million tons of CO_2e are emitted due to removal of forest plants and decomposition of forest litter, and possibly significantly more from the mining "spoil" and lost soil carbon.

The fate of soil carbon and the fate of mining spoil, which contains high levels of coal fragments, termed "geogenic organic carbon," are extremely uncertain and the results depend on mining practices at particular sites; but they may represent significant emissions. The Fox and Campbell[38] analysis determined that the worst-case scenario is that all soil carbon is lost and that all carbon in mining spoil is emitted—representing emissions of up to 2.6 million tons CO_2e from soil and 27.5 million tons CO_2e from mining spoil. In this analysis, the 6 million tons CO_2e from forest plants and forest litter represents our low and best estimates for all coal use, and 37 million tons CO_2e (the sum of the high bound of forest plants and litter, geogenic organic carbon, and the forest soil emissions) represents our high, upper bound estimate of emissions for all coal use. In the years Fox and Campell studied, 90.5% of coal was used for electricity, so we attribute 90.5% of these emissions to coal-derived power.[2] To monetize and bound our estimate for damages due to emissions from land disturbance, our point estimate for the cost was calculated using a social cost of carbon of $30/ton CO_2e and our point estimate for emissions; the high-end estimate was calculated using the high-end estimate of emissions and a social cost of carbon of $100/ton CO_2e; and the low estimate was calculated using the point estimate for emissions and the $10/ton low estimate for the social cost of carbon.[20] Our best estimate is therefore $162.9 million, with a range from $54.3 million and $3.35 billion, or 0.008¢/kWh, ranging from 0.003 ¢/kWh to 0.166 ¢/kWh.

The physical vulnerabilities for communities near MTR sites include mudslides and dislodged boulders and trees, and flash floods, especially following heavy rain events. With climate change, heavy rainfall events (2, 4, and 6 inches/day) have increased in the continental United States since 1970, 14%, 20%, and 27% respectively.[39,40]

Blasting to clear mountain ridges adds an additional assault to surrounding communities.[16] The blasts can damage houses, other buildings, and infrastructure, and there are numerous anecdotal reports that the explosions and vibrations are taking a toll on the mental health of those living nearby.

Additional impacts include losses in property values, timber resources, crops (due to water contamination), plus harm to tourism, corrosion of buildings and monuments, dust from mines and explosions, ammonia releases (with formation of ammonium nitrate), and releases of methane.[41]

Methane

In addition to being a heat-trapping gas of high potency, methane adds to the risk of explosions, and fires at mines.[20,42] As of 2005, global atmospheric methane levels were approximately 1,790 parts per billion (ppb), which is an 27 ppb increase over 1998.[43] Methane is emitted during coal mining and it is 25 times more potent than CO_2 during a 100-year timeframe (this is the 100-year global warming potential, a common metric in climate science and policy used to normalize different GHGs to carbon equivalence). When methane decays, it can yield CO_2, an effect that is not fully assessed in this equivalency value.[43]

According to the EIA,[2] 71,100,000 tons CO_2e of methane from coal were emitted in 2007 but

Table 1. **The life cycle impact of the U.S. coal industry**

	Economic	Human health	Environment	Other
Underground coal mining	1. Federal and state subsidies of coal industry	1. Increased mortality and morbidity in coal communities due to mining pollution	1. Methane emissions from coal leading to climate change	
		2. Threats remaining from abandoned mine lands	2. Remaining damage from abandoned mine lands	
MTR mining	1. Tourism loss	1. Contaminated streams	1. Loss of biodiversity	
	2. Significantly lower property values	2. Direct trauma in surrounding communities	2. Sludge and slurry ponds	
	3. Cost to taxpayers of environmental mitigation and monitoring (both mining and disposal stages)	3. Additional mortality and morbidity in coal communities due to increased levels of air particulates associated with MTR mining (vs. underground mining)	3. Greater levels of air particulates	
	4. Population declines	4. Higher stress levels	4. Loss and contamination of streams	
Coal mining	1. Opportunity costs of bypassing other types of economic development (especially for MTR mining)	1. Workplace fatalities and injuries of coal miners	1. Destruction of local habitat and biodiversity to develop mine site	1. Infrastructure damage due to mudslides following MTR
	2. Federal and state subsidies of coal industry	2. Morbidity and mortality of mine workers resulting from air pollution (e.g., black lung, silicosis)	2. Methane emissions from coal leading to climate change	2. Damage to surrounding infrastructure from subsidence
	3. Economic boom and bust cycle in coal mining communities	3. Increased mortality and morbidity in coal communities due to mining pollution	3. Loss of habitat and streams from valley fill (MTR)	3. Damages to buildings and other infrastructure due to mine blasting
	4. Cost of coal industry litigation	4. Increased morbidity and mortality due to increased air particulates in communities proximate to MTR mining	4. Acid mine drainage	4. Loss of recreation availability in coal mining communities

Continued

Table 1. *Continued*

	Economic	Human health	Environment	Other
	5. Damage to farmland and crops resulting from coal mining pollution	5. Hospitalization costs resulting from increased morbidity in coal communities	5. Incomplete reclamation following mine use	5. Population losses in abandoned coal-mining communities
		6. Local health impacts of heavy metals in coal slurry	6. Water pollution from runoff and waste spills	
	6. Loss of income from small scale forest gathering and farming (e.g., wild ginseng, mushrooms) due to habitat loss	7. Health impacts resulting from coal slurry spills and water contamination	7. Remaining damage from abandoned mine lands	
	7. Loss of tourism income	8. Threats remaining from abandoned mine lands; direct trauma from loose boulders and felled trees	8. Air pollution due to increased particulates from MTR mining	
	8. Lost land required for waste disposal	9. Mental health impacts		
	9. Lower property values for homeowners	10. Dental health impacts reported, possibly from heavy metals		
	10. Decrease in mining jobs in MTR mining areas	11. Fungal growth after flooding		
Coal transportation	1. Wear and tear on aging railroads and tracks	1. Death and injuries from accidents during transport	1. GHG emissions from transport vehicles	1. Damage to rail system from coal transportation
		2. Impacts from emissions during transport	2. Damage to vegetation resulting from air pollution	2. Damage to roadways due to coal trucks
Coal combustion	1. Federal and state subsidies for the coal industry	1. Increased mortality and morbidity due to combustion pollution	1. Climate change due to CO_2 and NO_x derived N_2O emissions	1. Corrosion of buildings and monuments from acid rain
	2. Damage to farmland and crops resulting from coal combustion pollution	2. Hospitalization costs resulting from increased morbidity in coal communities	2. Environmental contamination as a result of heavy metal pollution (mercury, selenium, arsenic)	2. Visibility impairment from NO_x emissions

Continued

Table 1. *Continued*

	Economic	Human health	Environment	Other
		3. Higher frequency of sudden infant death syndrome in areas with high quantities of particulate pollution	3. Impacts of acid rain derived from nitrogen oxides and SO_2	
		4. See Levy *et al.*[21]	4. Environmental impacts of ozone and particulate emissions	
			5. Soil contamination from acid rain	
			6. Destruction of marine life from mercury pollution and acid rain	
			7. Freshwater use in coal powered plants	
Waste disposal		1. Health impacts of heavy metals and other contaminants in coal ash and other waste	1. Impacts on surrounding ecosystems from coal ash and other waste	
		2. Health impacts, trauma and loss of property following coal ash spills	2. Water pollution from runoff and fly ash spills	
Electricity transmission	1. Loss of energy in the combustion and transmission phases		1. Disturbance of ecosystems by utility towers and rights of way	1. Vulnerability of electrical grid to climate change associated disasters

only 92.7% of this coal is going toward electricity. This results in estimated damages of $2.05 billion, or 0.08¢/kWh, with low and high estimates of $684 million and $6.84 billion, or 0.034¢/kWh, and 0.34¢/kWh, using the low and high estimates for the social cost of carbon.[20] Life cycle assessment results, based on 2004 data and emissions from a subset of power plants, indicated 0.037 kg of CO_2e of methane emitted per kWh of electricity produced. With the best estimate for the social cost of carbon, this leads to an estimated cost of $2.2 billion, or 0.11¢/kWh. The differences are due to differences in data, and data from a different years. (See Fig. 1 for summary of external costs per kWh.)

Impoundments

Impoundments are found all along the periphery and at multiple elevations in the areas of MTR sites; adjacent to coal processing plants; and as coal combustion waste ("fly ash") ponds adjacent to coal-fired power plants.[47] Their volume and composition have not been calculated.[48] For Kentucky, the number of known waste and slurry ponds alongside MTR sites and processing plants is 115.[49] These

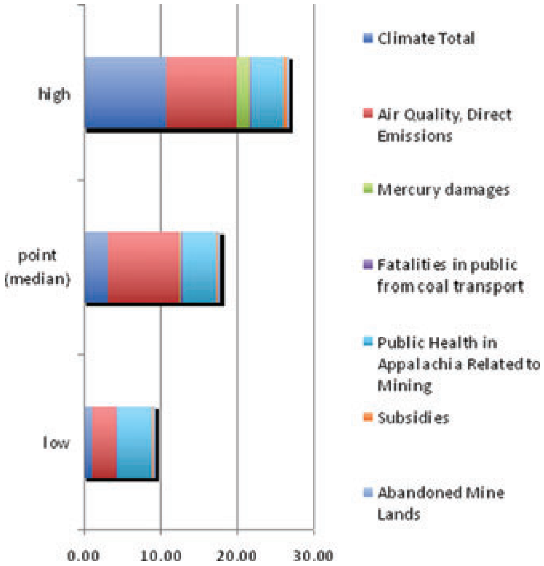

Figure 1. This graph shows the best estimates of the externalities due to coal, along with low and high estimates, normalized to ¢ per kWh of electricity produced. (In color in *Annals* online.)

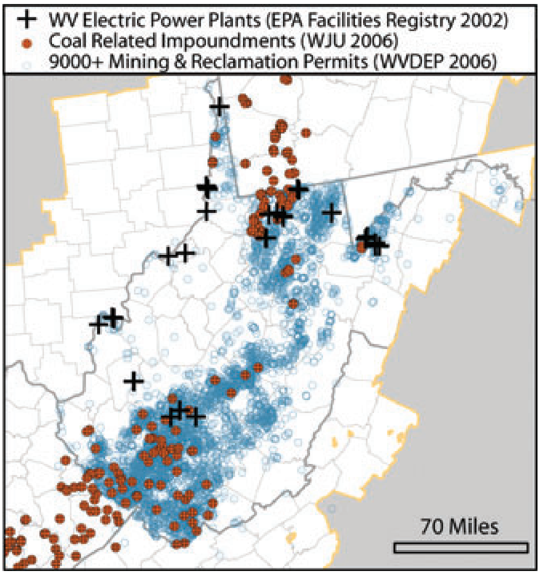

Figure 2. Electric power plants, impoundments (sludge and slurry ponds, CCW, or "fly ash"), and sites slated for reclamation in West Virginia.[44–46] (In color in *Annals* online.) Source: Hope Childers, Wheeling Jesuit University.

sludge, slurry and coal combustion waste (CCW) impoundments are considered by the EPA to be significant contributors to water contamination in the United States. This is especially true for impoundments situated atop previously mined and potentially unstable sites. Land above tunnels dug for long-haul and underground mining are at risk of caving. In the face of heavier precipitation events, unlined containment dams, or those lined with dried slurry are vulnerable to breaching and collapse (Fig. 2).

Processing plants

After coal is mined, it is washed in a mixture of chemicals to reduce impurities that include clay, non-carbonaceous rock, and heavy metals to prepare for use in combustion.[50] Coal slurry is the byproduct of these coal refining plants. In West Virginia, there are currently over 110 billion gallons of coal slurry permitted for 126 impoundments.[49,51] Between 1972 and 2008, there were 53 publicized coal slurry spills in the Appalachian region, one of the largest of which was a 309 million gallon spill that occurred in Martin County, KY in 2000.[48] Of the known chemicals used and generated in processing coal, 19 are known cancer-causing agents, 24 are linked to lung and heart damage, and several remain untested as to their health effects.[52,53]

Coal combustion waste or fly ash

CCW or fly ash—composed of products of combustion and other solid waste—contains toxic chemicals and heavy metals; pollutants known to cause cancer, birth defects, reproductive disorders, neurological damage, learning disabilities, kidney disease, and diabetes.[47,54] A vast majority of the over 1,300 CCW impoundment ponds in the United States are poorly constructed, increasing the risk that waste may leach into groundwater supplies or nearby bodies of water.[55] Under the conditions present in fly ash ponds, contaminants, particularly arsenic, antimony, and selenium (all of which can have serious human health impacts), may readily leach or migrate into the water supplied for household and agricultural use.[56]

According to the EPA, annual production of CCW increased 30% per year between 2000 and 2004, to 130 million tons, and is projected to increase to over 170 million tons by 2015.[57] Based on a series of state estimates, approximately 20% of the total is injected into abandoned coal mines.[58]

In Kentucky, alone, there are 44 fly ash ponds adjacent to the 22 coal-fired plants. Seven of these ash ponds have been characterized as "high hazard" by the EPA, meaning that if one of these impoundments spilled, it would likely cause significant property damage, injuries, illness, and deaths. Up to 1 in 50 residents in Kentucky, including 1 in 100 children, living near one of the fly ash ponds are at risk of developing cancer as a result of water- and air-borne exposure to waste.[47]

Box 3.

Tennessee Valley Authority Fly Ash Pond Spill

On December 2, 2008 an 84-acre CCW containment area spilled when the dike ruptured at the Tennessee Valley Authority Kingston Fossil Plant CCW impoundment, following heavy rains. Over one billion gallons of fly ash slurry spilled across 300 acres.

Local water contamination

Over the life cycle of coal, chemicals are emitted directly and indirectly into water supplies from mining, processing, and power plant operations. Chemicals in the waste stream include ammonia, sulfur, sulfate, nitrates, nitric acid, tars, oils, fluorides, chlorides, and other acids and metals, including sodium, iron, cyanide, plus additional unlisted chemicals.[16,50]

Spath and colleagues[50] found that these emissions are small in comparison to the air emissions. However, a more recent study performed by Koornneef and colleagues[59] using up-to-date data on emissions and impacts, found that emissions and seepage of toxins and heavy metals into fresh and marine water were significant. Elevated levels of arsenic in drinking water have been found in coal mining areas, along with ground water contamination consistent with coal mining activity in areas near coal mining facilities.[16,17,60,61] In one study of drinking water in four counties in West Virginia, heavy metal concentrations (thallium, selenium, cadmium, beryllium, barium, antimony, lead, and arsenic) exceeded drinking water standards in one-fourth of the households.[48] This mounting evidence indicates that more complete coverage of water sampling is needed throughout coal-field regions.

Carcinogen emissions

Data on emissions of carcinogens due to coal mining and combustion are available in the Ecoinvent database.[25] The eco-indicator impact assessment method was used to estimate health damages in disability-adjusted life years due to these emissions,[25] and were valued using the VSL-year.[26] This amounted to \$11 billion per year, or 0.6 ¢/kWh, though these may be significant underestimates of the cancer burden associated with coal.

Of the emissions of carcinogens in the life cycle inventory (inventory of all environmental flows) for coal-derived power, 94% were emitted to water, 6% to air, and 0.03% were to soil, mainly consisting of arsenic and cadmium (note: these do not sum to 100% due to rounding).[25] This number is not included in our total cost accounting to avoid double counting since these emissions may be responsible for health effects observed in mining communities.

Mining and community health

A suite of studies of county-level mortality rates from 1979–2004 by Hendryx found that all-cause mortality rates,[62] lung cancer mortality rates,[60] and mortality from heart, respiratory, and kidney disease[17] were highest in heavy coal mining areas of Appalachia, less so in light coal mining areas, lesser still in noncoal mining areas in Appalachia, and lowest in noncoal mining areas outside of Appalachia. Another study performed by Hendryx and Ahern[18] found that self-reports revealed elevated rates of lung, cardiovascular and kidney diseases, and diabetes and hypertension in coal-mining areas. Yet, another study found that for pregnant women, residing in coal mining areas of West Virginia posed an independent risk for low birth weight (LBW) infants, raising the odds of an LBWs infant by 16% relative to women residing in counties without coal mining.[63] LBW and preterm births are elevated,[64] and children born with extreme LBW fare worse than do children with normal birth weights in almost all neurological assessments;[65] as adults, they have more chronic diseases, including hypertension and diabetes mellitus.[66] Poor birth outcomes are especially elevated in areas with MTR mining as compared with areas with other forms of mining.[67] MTR mining has increased in the areas studied, and is occurring close to population centers.[62]

The estimated excess mortality found in coal mining areas is translated into monetary costs using the VSL approach. For the years 1997–2005, excess age-adjusted mortality rates in coal mining areas of Appalachia compared to national rates

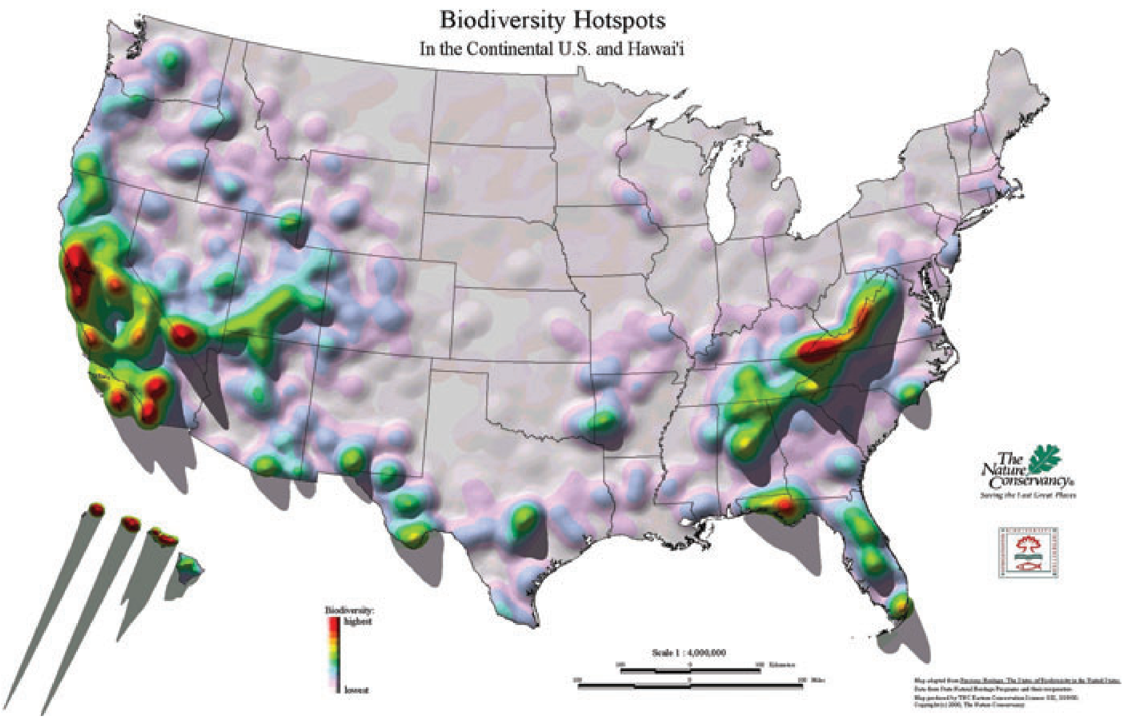

Figure 3. Areas of highest biological diversity in the continental United States. Source: The Nature Conservancy, Arlington, VA. (In color in *Annals* online.)

outside Appalachia translates to 10,923 excess deaths every year, with 2,347 excess deaths every year after, adjusting for other soci-oeconomic factors, including smoking rates, obesity, poverty, and access to health care. These socio-economic factors were statistically significantly worse in coal-mining areas.[18,62,68]

Using the VSL of $7.5 million,[20] the unadjusted mortality rate, and the estimate that 91% of coal during these years was used for electricity,[2] this translates to a total cost of $74.6 billion, or 4.36¢/kWh. In contrast, the authors calculated the direct (monetary value of mining industry jobs, including employees and proprietors), indirect (suppliers and others connected to the coal industry), and induced (ripple or multiplier effects throughout the economies) economic benefits of coal mining to Appalachia, and estimated the benefits to be $8.08 billion in 2005 US$.

Ecological impacts

Appalachia is a biologically and geologically rich region, known for its variety and striking beauty. There is loss and degradation of habitat from MTR; impacts on plants and wildlife (species losses and species impacted) from land and water contamination, and acid rain deposition and altered stream conductivity; and the contributions of deforestation and soil disruption to climate change.[16,20]

Globally, the rich biodiversity of Appalachian headwater streams is second only to the tropics.[69] For example, the southern Appalachian mountains harbor the greatest diversity of salamanders globally, with 18% of the known species world-wide (Fig. 3).[69]

Imperiled aquatic ecosystems

Existence of viable aquatic communities in valley fill permit sites was first elucidated in court testimony leading to the "Haden decision."[70] An interagency study of 30 streams in MTR mining-permit areas focused on the upper, unmapped reaches of headwater streams in West Virginia and Kentucky.[71] In performing this study, the researchers identified 71 genera of aquatic insects belonging to 41 families within eight insect orders. The most widely distributed taxa in 175 samples were found in abundance in 30 streams in five areas slated to undergo MTR.

Electrical conductivity (a measure of the concentration of ions) is used as one indicator of stream health.[72] The EPA recommends that stream conductivity not exceed 500 microsiemens per cm (*u*S/cm). In areas with the most intense mining, in which 92% of the watershed had been mined, a recent study revealed levels of 1,100 *u*S/cm.[72]

Meanwhile, even levels below 500 *u*S/cm were shown to significantly affect the abundance and composition of macroinvertebrates, such as mayflies and caddis flies.[73] "Sharp declines" were found in some stream invertebrates where only 1% of the watershed had been mined.[74,75]

Semivoltine aquatic insects (e.g., many stoneflies and dragonflies)—those that require multiple years in the larval stage of development—were encountered in watersheds as small as 10–50 acres. While many of these streams become dry during the late summer months, they continue to harbor permanent resident taxonomic groups capable of withstanding summer dry conditions. Salamanders, the top predatory vertebrates in these fishless headwater streams, depend on permanent streams for their existence.

Mussels are a sensitive indicator species of stream health. Waste from surface mines in Virginia and Tennessee running off into the Clinch and Powell Rivers are overwhelming and killing these filter feeders, and the populations of mussels in these rivers has declined dramatically. Decreases in such filter feeders also affect the quality of drinking water downstream.[76]

In addition, stream dwelling larval stages of aquatic insects are impossible to identify to the species level without trapping adults or rearing larvae to adults.[77] However, no studies of adult stages are conducted for mining-permit applications.

The view that—because there are so many small streams and brooks in the Appalachians—destroying a portion represents a minor threat to biodiversity is contrary to the science. As the planet's second-oldest mountain range, geologically recent processes in Appalachia in the Pleistocene epoch (from 2.5 million to 12,000 years ago) have created conditions for diversification, resulting in one of the U.S. biodiversity "hotspots" (Fig. 3).

Thus, burying an entire 2,000 hectare watershed, including the mainstream and tributaries, is likely to eliminate species of multiple taxa found only in Appalachia.

Researchers have concluded that many unknown species of aquatic insects have likely been buried under valley fills and affected by chemically contaminated waterways. Today's Appalachian coal mining is undeniably resulting in loss of aquatic species, many of which will never be known. Much more study is indicated to appreciate the full spectrum of the ecological effects of MTR mining.[78]

Transport

There are direct hazards from transport of coal. People in mining communities report that road hazards and dust levels are intense. In many cases dust is so thick that it coats the skin, and the walls and furniture in homes.[41] This dust presents an additional burden in terms of respiratory and cardiovascular disease, some of which may have been captured by Hendryx and colleagues.[17–19,60,62,67,68,79]

With 70% of U.S. rail traffic devoted to transporting coal, there are strains on the railroad cars and lines, and (lost) opportunity costs, given the great need for public transport throughout the nation.[20]

The NRC report[20] estimated the number of railroad fatalities by multiplying the proportion of revenue-ton miles (the movement of one ton of revenue-generating commodity over one mile) of commercial freight activity on domestic railroads accounted for by coal, by the number of public fatalities on freight railroads (in 2007); then multiplied by the proportion of transported coal used for electricity generation. The number of coal-related fatalities was multiplied by the VSL to estimate the total costs of fatal accidents in coal transportation. A total of 246 people were killed in rail accidents during coal transportation; 241 of these were members of the public and five of these were occupational fatalities. The deaths to the public add an additional cost of $1.8 billion, or 0.09¢/kWh.

Social and employment impacts

In Appalachia, as levels of mining increase, so do poverty rates and unemployment rates, while educational attainment rates and household income levels decline.[19]

While coal production has been steadily increasing (from 1973 to 2006), the number of employees at the mines increased dramatically from 1973 to 1979, then decreased to levels below 1973 employment levels.[27] Between 1985 and 2005 employment in the Appalachian coal mining industry declined by 56% due to increases in mechanization for MTR and other surface mining.[19,27] There are 6,300 MTR and surface mining jobs in West Virginia, representing 0.7–0.8% of the state labor force.[2] Coal companies are also employing more people through temporary mining agencies and populations are shifting: between 1995 and 2000 coal-mining West Virginian counties experienced a net loss of 639 people to migration compared with a net migration gain of 422 people in nonmining counties.[19,80]

Combustion

The next stage in the life cycle of coal is combustion to generate energy. Here we focus on coal-fired electricity-generating plants. The by-products of coal combustion include CO_2, methane, particulates and oxides of nitrogen, oxides of sulfur, mercury, and a wide range of carcinogenic chemicals and heavy metals.[20]

Long-range air pollutants and air quality. Data from the U.S. EPA's Emissions & Generation Resource Integrated Database (eGRID)[81] and National Emissions Inventory (NEI)[82] demonstrates that coal power is responsible for much of the U.S. power generation-related emissions of $PM_{2.5}$ (51%), NO_x (35%), and SO_2 (85%). Along with primary emissions of the particulates, SO_2 and NO_x contribute to increases in airborne particle concentrations through secondary transformation processes.[20,21,83]

Studies in New England[84] find that, although populations within a 30-mile radius of coal-fired power plants make up a small contribution to aggregate respiratory illness, on a per capita basis, the impacts on those nearby populations are two to five times greater than those living at a distance. Data in Kentucky suggest similar zones of high impact.

The direct health impacts of SO_2 include respiratory illnesses—wheezing and exacerbation of asthma, shortness of breath, nasal congestion, and pulmonary inflammation—plus heart arrhythmias, LBW, and increased risk of infant death.

The nitrogen-containing emissions (from burning all fossil fuels and from agriculture) cause damages through several pathways. When combined with volatile organic compounds, they can form not only particulates but also ground-level ozone (photochemical smog). Ozone itself is corrosive to the lining of the lungs, and also acts as a local heat-trapping gas.

Epidemiology of air pollution. Estimates of nonfatal health endpoints from coal-related pollutants vary, but are substantial—including 2,800 from lung cancer, 38,200 nonfatal heart attacks and tens of thousands of emergency room visits, hospitalizations, and lost work days.[85] A review[83] of the epidemiology of airborne particles documented that exposure to $PM_{2.5}$ is linked with all-cause premature mortality, cardiovascular and cardiopulmonary mortality, as well as respiratory illnesses, hospitalizations, respiratory and lung function symptoms, and school absences. Those exposed to a higher concentration of $PM_{2.5}$ were at higher risk.[86] Particulates are a cause of lung and heart disease, and premature death,[83] and increase hospitalization costs. Diabetes mellitus enhances the health impacts of particulates[87] and has been implicated in sudden infant death syndrome.[88] Pollution from two older coal-fired power plants in the U.S. Northeast was linked to approximately 70 deaths, tens of thousands of asthma attacks, and hundreds of thousands of episodes of upper respiratory illnesses annually.[89]

A reanalysis of a large U.S. cohort study on the health effects of air pollution, the Harvard Six Cities Study, by Schwartz *et al.*[90] used year-to-year changes in $PM_{2.5}$ concentrations instead of assigning each city a constant $PM_{2.5}$ concentration. To construct one composite estimate for mortality risk from $PM_{2.5}$, the reanalysis also allowed for yearly lags in mortality effects from exposure to $PM_{2.5}$, and revealed that the relative risk of mortality increases by 1.1 per 10 $\mu g/m^3$ increase in $PM_{2.5}$ the year of death, but just 1.025 per 10 $\mu g/m^3$ increase in $PM_{2.5}$ the year before death. This indicates that most of the increase in risk of mortality from $PM_{2.5}$ exposure occurs in the same year as the exposure. The reanalysis also found little evidence for a threshold, meaning that there may be no "safe" levels of $PM_{2.5}$ and that all levels of $PM_{2.5}$ pose a risk to human health.[91]

Thus, prevention strategies should be focused on continuous reduction of $PM_{2.5}$ rather than on peak days, and that air quality improvements will have effect almost immediately upon implementation. The U.S. EPA annual particulate concentration standard is set at 15.0 $\mu g/m^3$, arguing that there is no evidence for harm below this level.[92] The results of the Schwartz *et al.*[90] study directly contradict this line of reasoning.

Risk assessment. The risk assessment performed by the NRC,[20] found aggregate damages of $65 billion, including damages to public health, property, crops, forests, foregone recreation, and visibility due to emissions from coal-fired power plants of $PM_{2.5}$, PM_{10}, SO_2, NO_x, volatile organic compounds, and ozone. The public health damages included mortality cases, bronchitis cases, asthma cases, hospital admissions related to respiratory, cardiac, asthma, coronary obstructive pulmonary disease, and ischemic heart disease problems, and emergency room visits related to asthma. On a plant-by-plant basis after being normalized to electricity produced by each plant, this was 3.2 ¢/kWh. Plant-by-plant estimates of the damages ranged from 1.9 ¢/kWh to 12 ¢/kWh. Plant-to-plant variation was largely due to controls on the plant, characteristics of the coal, and the population downwind of the plant. Emissions of SO_2 were the most damaging of the pollutants affecting air quality, and 99% of this was due to SO_2 in the particle form.[20] The NRC study found that over 90% of the damages due to air quality are from $PM_{2.5}$-related mortality, which implies that these damages included approximately 8,158 excess mortality cases.[20] For the state of Kentucky alone, for each ton of SO_2 removed from the stack, the NRC (2009)[20] calculated a public health savings of $5,800. Removing the close to 500,000 tons emitted in Kentucky would save over $2.85 billion annually. The life cycle analysis found that damages from air quality public health impacts, monetized using methods from ExternE[26] are approximately $70.5 billion, which is roughly in line with this number.

The NRC's estimate is likely an underestimate, since the NRC used the concentration-response curve from Pope and Dockery,[83] which provides a low estimate for increases in mortality risk with increases in $PM_{2.5}$ exposure and is an outlier when compared to other studies examining the $PM_{2.5}$–mortality relationship.[6,87] Had they used the result of the more recent study by Schwartz *et al.*,[90] which was used in a similar study by Levy *et al.*,[21] or the number from Dockery *et al.*,[93] the value they calculated would have been approximately three times higher,[20] therefore implying 24,475 excess deaths in 2005, with a cost of $187.5 billion, or 9.3¢/kWh. As the Schwartz *et al.* study is more recent, uses elaborate statistical techniques to derive the concentration-response function for $PM_{2.5}$ and mortality, and is now widely accepted,[21,94] we use it here to derive our best and high estimate, and the Pope and Dockery,[83] estimate to derive our low. Our best and high estimates for the damages due to air quality detriment impacts are both $187.5 billion, and our low is $65 billion. On a per-kWh basis, this is an average cost of 9.3 ¢/kWh with a low estimate of 3.2 ¢/kWh.

Atmospheric nitrogen deposition. In addition to the impacts to air quality and public health, nitrogen causes ecological harm via eutrophication. Eutrophication, caused by excess nitrogen inputs to coastal river zones, is the greatest source of water quality alteration in the United States and atmospheric deposition is one of the dominant sources of nitrogen inputs.[95] In an analysis by Jaworkski *et al.*,[95] prepared for the EPA, 10 benchmark watersheds in the U.S. Northeast that flowed into the Atlantic coastal zone with good historical data were analyzed in conjunction with emissions data and reconstructed historical emissions. They found that the contribution to riverine nitrogen from nitrogen deposited from the air ranged from 36% to 80%, with a mean of 64%.

The other primary sources of nitrogen are fertilizers from point (e.g., river) discharges and nonpoint (e.g., agricultural land) sources, and other point sources including sewage from cities and farm animals, especially concentrated animal feeding operations.[95] Anthropogenic contributions of nitrogen are equal to the natural sources, doubling this form of fertilization of soils and water bodies.[96]

Harmful algal blooms and dead zones

Ocean and water changes are not usually associated with coal. But nitrogen deposition is a by-product of combustion and the EPA[97] has reached consensus on the link between aquatic eutrophication and harmful algal blooms (HABs), and concluded that nutrient over-fertilization is one of the reasons for their expansion in the United States and other nations. HABs are characterized by discolored water, dead and dying fish, and respiratory irritants in the air, and have impacts including illness and death, beach closures, and fish, bird, and mammal die-offs from exposure to toxins. Illnesses in humans include gastroenteritis, neurological deficits, respiratory illness, and diarrheic, paralytic, and neurotoxic shellfish poisonings.

N_2O from land clearing is a heat-trapping gas[38,42] and adds to the nitrogen deposited in soils and water bodies. The nitrogen is also a contributor to fresh and sea water acidification.[98–100] Other factors include the loss of wetlands that filter discharges.[98–100]

The economic losses from HABs are estimated to be over $82 million/year in the United States, based on the most prominent episodes.[101,102] The full economic costs of HABs include public health impacts and health care costs, business interruptions of seafood and other allied industries (such as tourism and recreation, unemployment of fin- and shellfish fisherman and their families), and disruptions of international trade.[98–100]

The overfertilization of coastal zones worldwide has also led to over 350 "dead zones" with hypoxia, anoxia, and death of living marine organisms. Commercial and recreational fisheries in the Gulf of Mexico generate $2.8 billion annually[103] and losses from the heavily eutrophied Gulf of Mexico dead zone put the regional economy at risk.

Acid precipitation. In addition to the health impacts of SO_2, sulfates contribute to acid rain, decreased visibility, and have a greenhouse cooling influence.[20]

The long-term Hubbard Brook Ecosystem Study[104] has demonstrated that acid rain (from sulfates and nitrates) has taken a toll on stream and lake life, and soils and forests in the United States, primarily in the Northeast. The leaching of calcium from soils is widespread and, unfortunately, the recovery time is much longer than the time it takes for calcium to become depleted under acidic conditions.[105]

No monetized values of costs were found but a value for the benefits of improvements to the Adirondack State Park from acid rain legislation was produced by Resources for the Future, and found benefits ranging from $336 million to $1.1 billion per year.[106]

Mercury. Coal combustion in the U.S. releases approximately 48 tons of the neurotoxin mercury each year.[54] The most toxic form of mercury is methylmercury, and the primary route of human exposure is through consumption of fin- and shellfish containing bioaccumulated methylmercury.[107] Methylmercury exposure, both dietary and *in utero* through maternal consumption, is associated with neurological effects in infants and children, including delayed achievement of developmental milestones and poor results on neurobehavioral tests—attention, fine motor function, language, visual-spatial abilities, and memory. Seafood consumption has caused 7% of women of childbearing age to exceed the mercury reference dose set by the EPA, and 45 states have issued fish consumption advisories.[107] Emission controls specific to mercury are not available, though 74–95% of emitted mercury is captured by existing emissions control equipment. More advanced technologies are being developed and tested.[107]

Direct costs of mercury emissions from coal-fired power plants causing mental retardation and lost productivity in the form of IQ detriments were estimated by Trasande *et al.*[22,23] to be $361.2 million and $1.625 billion, respectively, or 0.02¢/kWh and 0.1¢/kWh, respectively. Low-end estimates for these values are $43.7 million and $125 million, or 0.003¢/kWh and 0.007¢/kWh; high-end estimates for these values are $3.3 billion and $8.1 billion, or 0.19¢/kWh and 0.48¢/kWh.

There are also epidemiological studies suggesting an association between methylmercury exposure and cardiovascular disease.[108] Rice *et al.*[109] monetized the benefits of a 10% reduction in mercury emissions for both neurological development and cardiovascular health, accounting for uncertainty that the relationship between cardiovascular disease and methylmercury exposure is indeed causal. Applying these results for the cardiovascular benefits of a reduction in methylmercury to the 41% of total U.S. mercury emissions from coal[22,23] indicates costs of $3.5 billion, with low and high estimates of $0.2 billion and $17.9 billion, or 0.2 ¢/kWh, with low and high estimates of 0.014 ¢/kWh and 1.05 ¢/kWh.

Coal's contributions to climate change

The Intergovernmental Panel on Climate Change (IPCC) reported that annual global GHG emissions have—between 1970 and 2004—increased 70% to 49.0 Gt CO_2-e/year.[109] The International Energy Agency's Reference Scenario estimates that worldwide CO_2 emissions will increase by 57% between 2005 and 2030, or 1.8% each year, to 41,905 Mt.[1] In the same time period, CO_2 emissions from coal-generated power are projected to increase 76.6% to 13,884 Mt.[1]

In 2005, coal was responsible for 82% of the U.S.'s GHG emissions from power generation.[110] In addition to direct stack emissions, there are methane emissions from coal mines, on the order of 3% of the stack emissions.[110] There are also additional GHG emissions from the other uses of coal, approximately 139 Mt CO_2.[1]

Particulate matter (black carbon or soot) is also a heat-trapping agent, absorbing solar radiation, and, even at great distances, decreasing reflectivity (albedo) by settling in snow and ice.[111–113] The contribution of particulates (from coal, diesel, and biomass burning) to climate change has, until recently, been underestimated. Though short-lived, the global warming potential per volume is 500 times that of CO_2.[111]

Climate change

Since the 1950s, the world ocean has accumulated 22 times as much heat as has the atmosphere,[114] and the pattern of warming is unmistakably attributable to the increase in GHGs.[115] Via this ocean repository and melting ice, global warming is changing the climate: causing warming, altered weather patterns, and sea level rise. Climate may change gradually or nonlinearly (in quantum jumps). The release of methane from Arctic seas and the changes in Earth's ice cover (thus albedo), are two potential amplifying feedbacks that could accelerate the rate of Earth's warming.

Just as we have underestimated the rate at which the climate would change, we have underestimated the pace of health and environmental impacts. Already the increases in asthma, heat waves, clusters of illnesses after heavy rain events and intense storms, and in the distribution of infectious diseases are apparent.[116,117] Moreover, the unfolding impacts of climate instability hold yet even more profound impacts for public health, as the changes threaten the natural life-supporting systems upon which we depend.

The EIA[2] estimated that 1.97 billion tons of CO_2 and 9.3 million tons CO_2e of N_2O were emitted directly from coal-fired power plants. Using the social cost of carbon, this resulted in a total cost of $61.7 billion, or 3.06 ¢/kWh. Using the low and high estimates of the social cost of carbon results in cost of $20.56 billion to $205.6 billion, or 1.02 ¢/kWh to 10.2 ¢/kWh.

Black carbon emissions were also calculated using data from the EPA's eGRID database[81] on electricity produced from lignite. The low, mean, and high energy density values for lignite[5] was then used to calculate the amount of lignite consumed. The Cooke *et al.*[118] emissions factor was used to estimate black carbon emissions based on lignite use and the Hansen *et al.*[111] global temperature potential was used to convert these emissions to CO_2e. This resulted in an estimate of 1.5 million tons CO_2e being emitted in 2008, with a value of $45.2 million, or 0.002¢/kWh. Using our low and high estimates for the social cost of carbon and the high and low values for the energy density of lignite produced values of $12.3 million to $161.4 million, or 0.0006 ¢/kWh to 0.008¢/kWh.

One measure of the costs of climate change is the rising costs of extreme weather events, though these are also a function of and real estate and insurance values. Overall, the costs of weather-related disasters rose 10-fold from the 1980s to the 1990s (from an average of $4 bn/year to $40 bn/year) and jumped again in the past decade, reaching $225 bn in 2005.[119] Worldwide, Munich Re—a company that insures insurers—reports that, in 2008, without Katrina-level disasters, weather-related "catastrophic losses" to the global economy were the third-highest in recorded history, topping $200 billion, including $45 billion in the United States.[120]

The total costs of climate change damages from coal-derived power, including black carbon, CO_2 and N_2O emissions from combustion, land disturbance in MTR, and methane leakage from mines, is $63.9 billion dollars, or 3.15 ¢/kWh, with low and high estimates of $21.3 billion to $215.9 billion, or 1.06 ¢/kWh to 10.71 ¢/kWh. A broad examination of the costs of climate change[121] projects global economic losses to between 5 and 20% of global gross domestic product ($1.75–$7 trillion in 2005 US$); the higher figure based on the potential collapse of ecosystems, such as coral reefs and widespread forest and crop losses. With coal contributing at least one-third of the heat-trapping chemicals, these projections offer a sobering perspective on the evolving costs of coal; costs that can be projected to rise (linearly or nonlinearly) over time.

Carbon capture and storage

Burning coal with CO_2 CCS in terrestrial, ocean, and deep ocean sediments are proposed methods of deriving "clean coal." But—in addition to the control technique not altering the upstream life cycle costs—significant obstacles lie in the way, including the costs of construction of suitable plants

Table 2. MIT cost estimates for some representative CCS systems.[5]

		Subcritical PC		Supercritical PC		Ultra-supercritical PC		SC PC-Oxy	IGCC	
		No capture	Capture	No capture	Capture	No capture	Capture	Capture	No capture	Capture
CCS performance	Coal feed (kg/hr)	208,000	284,000	184,894	242,950	164,000	209,000	232,628	185,376	228,115
	CO_2 emitted (kg/hr)	466,000	63,600	414,903	54,518	369,000	46,800	52,202	415,983	51,198
	CO_2 captured at 90%, (kg/h)	0	573.000	0	490662	0	422000	469817	0	460782
	CO_2 emitted (g/kWh)	931	127	830	109	738	94	104	832	102
CCS costs	$/kWh	1,280	2,230	1,330	2,140	1,360	2,090	1,900	1,430	1,890
	Total $, assuming 500 MW plant	$640,000,000	$1,115,000,000	$665,000,000	$1,070,000,000	$680,000,000	$1,045,000,000	$950,000,000	$715,000,000	$945,000,000
	Inv. Charce ¢/kWh @ 15.1%	2.6	4.52	2.7	4.34	2.76	4.24	3.85	2.9	3.83
	Fuel ¢/kWh @ $1.50/MMBtu	1.49	2.04	1.33	1.75	1.18	1.5	1.67	1.33	1.64
	O&M ¢/kWh	0.75	1.6	0.75	1.6	0.75	1.6	1.45	0.9	1.05
	COE ¢/kWh	4.84	8.16	4.78	7.69	4.69	7.34	8.98	5.13	6.52
	Cost of CO_2 avoided vs. same technology w/o capture ($/ton)		41.3		40.4		41.1	30.3		19.3
	Cost of CO_2 avoided vs. supercritical technology w/o capture ($/ton)		48.2		40.4		34.8	30.3		24
	Energy penalty		1,365,384,615		1,313,996,128		1,274,390,244			1,230,553,038

and underground storage facilities, and the "energy penalty" requiring that coal consumption per unit of energy produced by the power plant increase by 25–40% depending on the technologies used.[4,42]

Retrofitting old plants—the largest source of CO_2 in the United States—may exact an even larger energy penalty. The energy penalty means that more coal is needed to produce the same quantity of electricity, necessitating more mining, processing, and transporting of coal and resulting in a larger waste stream to produce the same amount of electricity. Coal-fired plants would still require locally polluting diesel trucks to deliver the coal, and generate CCW ponds that can contaminate ground water. Given current siting patterns, such impacts often fall disproportionately on economically disadvantaged communities. The energy penalty combined with other increased costs of operating a CCS plant would nearly double the cost of generating electricity from that plant, depending on the technology used (see Table 2).[5]

The U.S. Department of Energy estimates that an underground volume of 30,000 km^2 will be needed per year to reduce the CO_2 emissions from coal by 20% by 2050 (the total land mass of the continental U.S. (48 states) is 9,158,960 km^2).[122]

The safety and ensurability of scaling up the storage of the billion tons of CO_2 generated each year into the foreseeable future are unknown. Extrapolating from localized experiments, injecting fractions of the volumes that will have to be stored to make a significant difference in emissions, is fraught with numerous assumptions. Bringing CCS to scale raises additional risks, in terms of pressures underground. In addition to this, according to the U.S. Government Accountability Office (2008) there are regulatory, legal and liability uncertainties, and there is "significant cost of retrofitting existing plants that are single largest source of CO_2 emissions in the United States" (p. 7).[123]

Health and environmental risks of CCS

The Special IPCC Report on Carbon Dioxide Capture and Storage[42] lists the following concerns for CCS in underground terrestrial sites:

1. Storing compressed and liquefied CO_2 underground can acidify saline aquifers (akin to ocean acidification) and leach heavy metals, such as arsenic and lead, into ground water.[42]
2. Acidification of ground water increases fluid-rock interactions that enhance calcite dissolution and solubility, and can lead to fractures in

limestone ($CaCO_3$) and subsequent releases of CO_2 in high concentrations.[124]

3. Increased pressures may cause leaks and releases from previously drilled (often unmapped) pathways.
4. Increased pressures could destabilize underground faults and lead to earthquakes.
5. Large leaks and releases of concentrated CO_2 are toxic to plants and animals.[42]
    a. The 2006 Mammoth Mountain, CA release left dead stands of trees.[124]
6. Microbial communities may be altered, with release of other gases.[42]

The figures in Table 2 represent costs for new construction. Costs for retrofits (where CCS is installed on an active plant) and rebuilds (where CCS is installed on an active plant and the combustion technology is upgraded) are highly uncertain because they are extremely dependent on site conditions and precisely what technology the coal plant is upgraded to.[5] It does appear that complete rebuilds are more economically attractive than retrofits, and that "carbon-capture ready" plants are not economically desirable to build.[5]

Subsidies

In Kentucky, coal brings in an estimated $528 million in state revenues, but is responsible for $643 million in state expenditures. The net impact, therefore, is a loss of $115 million to the state of Kentucky.[126] These figures do not include costs of health care, lost productivity, water treatment for siltation and water infrastructure, limited development potential due to poor air quality, and social expenditures associated with declines in employment and related economic hardships of coal-field communities.[126]

The U.S. Federal Government provides subsides for electricity and mining activities, and these have been tallied by both the EIA and the Environmental Law Institute.[2,127,128] The EIA estimate is $3.17 billion of subsidies in 2007, or 0.16¢/kWh, and the Environmental Law Institute estimate is $5.37 billion for 2007, or 0.27¢/kWh.

Abandoned mine lands

Abandoned mine lands (AML) are those lands and waters negatively impacted by surface coal mining and left inadequately reclaimed or abandoned prior to August 3, 1977.[129] There are over 1,700 old abandoned mines in Pennsylvania, alone.[14] In some—like that in Centralia, PA—fires burn for decades, emitting carbon monoxide, and other fumes. The ground above others can open, and several people die each year falling into them. Still others flood and lead to contaminated ground water. Previous coal mining communities lie in the shadow of these disturbed areas. Officials in Pennsylvania estimate that it will take $15 billion over six decades to clean Pennsylvania's abandoned mines.

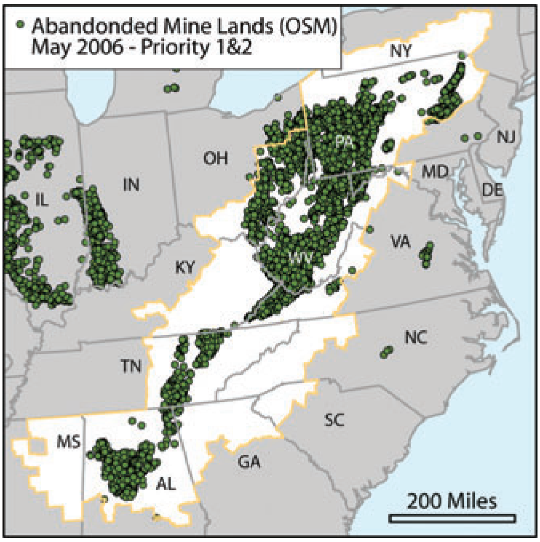

Figure 4. Current high-priority abandoned mine land reclamation sites from Alabama to Pennsylvania.[129] (In color in *Annals* online.) Source: Hope Childers, Wheeling Jesuit University.

Since the passage of the Surface Mining Control and Reclamation Act of 1977, active mining operations have been required to pay fees into the Abandoned Mine Reclamation Fund that are then used to finance reclamation of these AMLs.[129] Despite the more than $7.4 billion that has been collected as of September 30, 2005, there is a growing backlog of unfunded projects.[51] Data on the number and monetary value of unfunded AML projects remaining at the end of 2007 for the nation were collected directly from the Abandoned Mine Land Inventory System[129] and amounted to $8.8 billion 2008 US$, or 0.44¢/kWh (Fig. 4).

Results

The tabulation of the externalities in total and converted to 2008 US$ is given in Table 3 and normalized to cents per kWh of coal-generated electricity

Table 3. The complete costs of coal as reviewed in this report in 2008 US$.

	Monetized estimates from literature (2008 US$)			Monetized life cycle assessment results (2008 US$)	
	Low	Best	High	IPCC 2007, U.S. Hard Coal	U.S. Hard Coal Eco-indicator
Land disturbance	$54,311,510	$162,934,529	$3,349,209,766		
Methane emissions from mines	$684,084,928	$2,052,254,783	$6,840,849,276	$2,188,192, 405	
Carcinogens (mostly to water from waste)					$11,775,544, 263
Public health burden of communities in Appalachia	$74,612,823,575	$74,612,823,575	$74,612,823,575		
Fatalities in the public due to coal transport	$1,807,500,000	$1,807,500,000	$1,807,500,000		
Emissions of air pollutants from combustion	$65,094,911,734	$187,473,345,794	$187,473,345,794		$71,011,655, 364
Lost productivity from mercury emissions	$125,000,000	$1,625,000,000	$8,125,000,000		
Excess mental retardation cases from mercury emissions	$43,750,000	$361,250,000	$3,250,000,000		
Excess cardiovascular disease from mercury emissions	$246,000,000	$3,536,250,000	$17,937,500,000		
Climate damages from combustion emissions of CO_2 and N_2O	$20,559,709,242	$61,679,127,726	$205,597,092,419.52	$70,442,466, 509	
Climate damages from combustion emissions of black carbon	$12,346,127	$45,186,823	$161,381,512.28	$3,739,876, 478	
Environmental Law Institute estimate 2007			$5,373, 963,368		
EIA 2007	$3,177,964,157	$3,177, 964,157			
AMLs	$8,775,282,692	$8,775, 282,692	$8,775, 282,692		
Climate total	$21,310,451,806	$63,939,503,861	$215,948,532,974		
Total	$175,193,683,964	$345,308,920,080	$523,303,948,403		

A 2010 Clean Air Task Force[56] (CATF) report, with Abt Associates consulting, lists 13,000 premature deaths due to air pollution from all electricity generation in 2010, a decrease in their estimates from previous years. They attribute the drop to 105 scrubbers installed since 2005, the year in which we based our calculations. We were pleased to see improvements reported in air quality and health outcomes. There is, however, considerable uncertainty regarding the actual numbers. Using the epidemiology from the "Six Cities Study" implies up to 34,000 premature deaths in 2010. Thus, our figures are mid-range while those of the CATF represent the most conservative of estimates.

in Table 4. Our best estimate for the externalities related to coal is $345.3 billion (range: $175.2 bn to $523.3 bn). On a per-kWh basis this is 17.84¢/kWh, ranging from 9.42 ¢/kWh to 26.89 ¢/kWh.

Limitations of this analysis

While we have based this analysis on the best available data that are used by a wide range of organizations, this review is limited by the omission of many environmental, community, mental health, and economic impacts that are not easily quantifiable. Another limitation is the placing of numbers on impacts that are difficult to quantify or monetize, including the VSL, a crude estimate of the benefits of reducing the number of deaths used by economists, and the social cost of carbon, based on the evolving impacts of climate change. We have included ranges, reflecting the numerous sets of data and studies in this field (all of which have their own

Table 4. **Total costs of coal normalized to kWh of electricity produced.**

	Monetized estimates from literature in ¢/kWh of electricity (2008 US$)			Monetized life cycle assessment results in ¢/kWh of electricity (2008 US$)	
	Low	Best	High	IPCC 2007, U.S. Hard Coal	U.S. Hard Coal Eco-indicator
Land disturbance	0.00	0.01	0.17		
Methane emissions from mines	0.03	0.08	0.34	0.11	
Carcinogens (mostly to water from waste)					0.60
Public health burden of communities in Appalachia	4.36	4.36	4.36		
Fatalities in the public due to coal transport	0.09	0.09	0.09		
Emissions of air pollutants from combustion	3.23	9.31	9.31		3.59
Lost productivity from mercury emissions	0.01	0.10	0.48		
Excess mental retardation cases from mercury emissions	0.00	0.02	0.19		
Excess cardiovascular disease from mercury emissions	0.01	0.21	1.05		
Climate damage from combustion emissions of CO_2 and N_2O	1.02	3.06	10.20	3.56	
Climate damages from combustion emissions of black carbon	0.00	0.00	0.01	0.19	
Environmental Law Institute estimate 2007			0.27		
EIA 2007	0.16	0.16			
AMLs	0.44	0.44	0.44		
Climate total	1.06	3.15	10.7	3.75	1.54
Total	9.36	17.84	26.89		

uncertainties), varying assumptions in data sets and studies, and uncertainties about future impacts and the costs to society.

Some of the issues raised apply only to the region discussed. Decreased tourism in Appalachia, for example, affects regional economies; but may not affect the overall economy of the United States, as tourists may choose other destinations.

Studies in Australian coal mining communities illustrate the cycle of economic boom during construction and operation, the economic and worker decoupling from the fortunes of the mines; then the eventual closing.[130] Such communities experience high levels of depression and poverty, and increases in assaults (particularly sexual assaults), motor vehicle accidents, and crimes against property, until the culture shifts to allow for development of secondary industries. Additional evidence documents that mining-dependent economies tend to be weak economies,[131] and weak economic conditions in turn are powerful predictors of social and health disadvantages.[130,132]

Some values are also difficult to interpret, given the multiple baselines against which they must be compared. In assessing the "marginal" costs of environmental damages, we have assumed the diverse, pristine, hardwood forest that still constitutes the majority of the beautiful rich and rolling hills that make up the Appalachian Mountain range.

Ecological and health economic analyses are also affected by the discount rate used in such evaluations. Discount rates are of great value in assessing the worth of commodities that deteriorate over time. But they are of questionable value in assessing ecological, life-supporting systems that have value if they are sustained. Ecological economists might consider employing a negative discount rate—or an accrual rate—in assessing the true impacts of environmental degradation and the value of sustainability.

Finally, the costs reported here do not include a wide range of opportunity costs, including lost opportunities to construct wind farms and solar power plants, begin manufacture of wind turbines and solar technologies, develop technologies for the smart grid and transmission, and for economic and business development unrelated to the energy sector.

Conclusions

The electricity derived from coal is an integral part of our daily lives. However, coal carries a heavy burden. The yearly and cumulative costs stemming from the aerosolized, solid, and water pollutants associated with the mining, processing, transport, and combustion of coal affect individuals, families, communities, ecological integrity, and the global climate. The economic implications go far beyond the prices we pay for electricity.

Our comprehensive review finds that the best estimate for the total economically quantifiable costs, based on a conservative weighting of many of the study findings, amount to some $345.3 billion, adding close to 17.8¢/kWh of electricity generated from coal. The low estimate is $175 billion, or over 9¢/kWh, while the true monetizable costs could be as much as the upper bounds of $523.3 billion, adding close to 26.89¢/kWh. These and the more difficult to quantify externalities are borne by the general public.

Still these figures do not represent the full societal and environmental burden of coal. In quantifying the damages, we have omitted the impacts of toxic chemicals and heavy metals on ecological systems and diverse plants and animals; some ill-health endpoints (morbidity) aside from mortality related to air pollutants released through coal combustion that are still not captured; the direct risks and hazards posed by sludge, slurry, and CCW impoundments; the full contributions of nitrogen deposition to eutrophication of fresh and coastal sea water; the prolonged impacts of acid rain and acid mine drainage; many of the long-term impacts on the physical and mental health of those living in coal-field regions and nearby MTR sites; some of the health impacts and climate forcing due to increased tropospheric ozone formation; and the full assessment of impacts due to an increasingly unstable climate.

The true ecological and health costs of coal are thus far greater than the numbers suggest. Accounting for the many external costs over the life cycle for coal-derived electricity conservatively doubles to triples the price of coal per kWh of electricity generated.

Our analysis also suggests that the proposed measure to address one of the emissions—CO_2, via CCS—is costly and carries numerous health and environmental risks, which would be multiplied if CCS were deployed on a wide scale. The combination of new technologies and the "energy penalty" will, conservatively, almost double the costs to operate the utility plants. In addition, questions about the reserves of economically recoverable coal in the United States carry implications for future investments into coal-related infrastructure.

Public policies, including the Clean Air Act and New Source Performance Review, are in place to help control these externalities; however, the actual impacts and damages remain substantial. These costs must be accounted for in formulating public policies and for guiding private sector practices, including project financing and insurance underwriting of coal-fired plants with and without CCS.

Recommendations

1. Comprehensive comparative analyses of life cycle costs of all electricity generation

technologies and practices are needed to guide the development of future energy policies.

2. Begin phasing out coal and phasing in cleanly powered smart grids, using place-appropriate alternative energy sources.
3. A healthy energy future can include electric vehicles, plugged into cleanly powered smart grids; and healthy cities initiatives, including green buildings, roof-top gardens, public transport, and smart growth.
4. Alternative industrial and farming policies are needed for coal-field regions, to support the manufacture and installation of solar, wind, small-scale hydro, and smart grid technologies. Rural electric co-ops can help in meeting consumer demands.
5. We must end MTR mining, reclaim all MTR sites and abandoned mine lands, and ensure that local water sources are safe for consumption.
6. Funds are needed for clean enterprises, reclamation, and water treatment.
7. Fund-generating methods include:
   a. maintaining revenues from the workers' compensation coal tax;
   b. increasing coal severance tax rates;
   c. increasing fees on coal haul trucks and trains;
   d. reforming the structure of credits and taxes to remove misaligned incentives;
   e. reforming federal and state subsidies to incentivize clean technology infrastructure.
8. To transform our energy infrastructure, we must realign federal and state rules, regulations, and rewards to stimulate manufacturing of and markets for clean and efficient energy systems. Such a transformation would be beneficial for our health, for the environment, for sustained economic health, and would contribute to stabilizing the global climate.

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Conflicts of interest

The authors declare no conflicts of interest.

References

1. International Energy Agency. 2007. *World Energy Outlook 2007: China and India Insights*. International Energy Agency. Paris, France.
2. Energy Information Administration. 2010. U.S. Energy Information Administration. www.eia.doe.gov (accessed December 9, 2010).
3. Energy Information Administration. 2009. Annual Energy Outlook 2009, with Projections to 2030. 227 pp. U.S. Department of Energy. Washington, DC.
4. House, K.Z., C.F. Harvey, M.J. Aziz & D.P. Schrag. 2009. The energy penalty of post-combustion CO2 capture & storage and its implications for retrofitting the U.S. installed base. *Energy & Environmental Science* **2:** 193.
5. Katzer, J., E.J. Moniz, J. Deutch, *et al.* 2007. The future of coal: an interdisciplinary MIT study. Technical report, Massachusetts Institute of Technology, Cambridge, MA.
6. Energy Information Administration. 2010. Energy Information's Outlook Through 2035. From the Annual Energy Outlook 2010, Diane Kearney, Energy Information Administration, U.S. Department of Energy, Surface Transportation Board, March 23, 2010, Washington, DC.
7. Energy Information Administration. 2008. Annual Coal Report. http://www.eia.doe.gov/cneaf/coal/page/acr/acr_sum.html (accessed December 9, 2010).
8. Glustrom, L. 2009. Coal: Cheap and Abundant . . . Or Is It? http://www.cleanenergyaction.org/sites/default/files/Coal_Supply_Constraints_CEA_021209.pdf (accessed December 9, 2010).
9. Heinberg, R. 2009. *Blackout: Coal, Climate and the Last Energy Crisis*. Clairview Books. East Sussex, UK. 208pp.
10. Luppens, J. A. *et al.* 2008. *Assessment of Coal Geology, Resources, and Reserves in the Gillette Coalfield, Powder River Basin, Wyoming: U.S. Geological Survey Open-File Report 2008–1202.*
11. Ruppert, L.F, M.A. Kirschbaum, P.D. Warwick, *et al.* 2002. The US Geological Survey's national coal resource assessment: the results. *Internat. J. Coal Geo.* **50:** 247–274.
12. Patzek, T.W. & G.D. Croft. 2010. A global coal production forecast with multi-Hubbert cycle analysis. *Energy* **35:** 3109–3122.
13. Krauss, C. 2008. An export in solid supply. *New York Times.*
14. Goodell, J. 2006. *Big Coal: The Dirty Secret Behind America's Energy Future*. Houghton Mifflin. NY.

15. Ghose, M. 2007. Generation and quantification of hazardous dusts from coal mining in the Indian context. *Environ. Monit. Assess.* **130:** 35–45.
16. Palmer, M.A., E.S. Bernhardt, W.H. Schelsinger, *et al.* 2010. Science and regulation. Mountaintop mining consequences. *Science* **327:** 148–149.
17. Hendryx, M. 2009. Mortality from heart, respiratory, and kidney disease in coal mining areas of Appalachia. *Int. Arch. Occup. Environ. Health* **82:** 243–249.
18. Hendryx, M. & M. Ahern. 2008. Relations between health indicators and residential proximity to coal mining in West Virginia. *Am. J. of Public Health* **98:** 669–671.
19. Hendryx, M. & M. Ahern. 2009. Mortality in Appalachian coal mining regions: the value of statistical life lost. *Public Health Rep.* **124:** 541–550.
20. National Research Council. 2009. *The Hidden Costs of Energy: Unpriced Consequences of Energy Production.* Washington, DC.
21. Levy, J., L. Baxter & J. Schwartz. 2009. Uncertainty and variability in health-related damages from coal-fired power plants in the United States. *Risk Analysis* **29:** 1000–1014.
22. Trasande, L., P. Landrigan & C. Schechter. 2005. Public health and economic consequences of methyl mercury toxicity to the developing brain. *Environ. Health Perspect.* **113:** 590–596.
23. Trasande, L., C. Schechter, K. Haynes & P. Landrigan. 2006. Mental retardation and prenatal methylmercury toxicity. *Am. J. Ind. Med.* **49:** 153–158.
24. Epstein, P.R & J. Selber. 2002. *Oil: A Life Cycle Analysis of its Health and Environmental Impacts.* The Center for Health and the Global Environment. Harvard Medical School. Boston, MA.
25. Pré Consultants. 2008. SimaPro 7.1. http://www.pre.nl/ (accessed December 9, 2010).
26. Bickel, P. & R. Friedrich. Eds. 2004. *ExternE: Externalities of Energy. Methodology 2005 Update.* European Commission. Luxembourg.
27. Mine Safety and Health Administration. 2008. http://www.msha.gov/ (accessed December 9, 2010).
28. Yardley, J. 2008. As most of China celebrates New Years, a scramble continues in coal country. *New York Times*, February 9.
29. Jacobs, A. 2010. Rescuers in China struggle to free 153 trapped miners. *New York Times*, March 29.
30. National Institute for Occupational Safety and Health. 2008. What's New in the CWHSP. *NIOSH Coal Worker's Health Surveillance Program.* http://www.cdc.gov/niosh/topics/surveillance/ords/pdfs/CWHSP-News-Fall2008.pdf (accessed December 9, 2010).
31. Lloyd, J. W. 1971. Long-term mortality study of steelworkers V. Respiratory Cancer in coke plant workers. *J. Occ. Med.* **12:** 151–157.
32. Zeller, T.A. 2010. A battle in mining country pits coal against wind. *New York Times*, August 14.
33. U.S. Environmental Protection Agency. 2010. EPA Makes Announcement on Two Proposed West Virginia Mountaintop Coal Mines. *News Release.* http:// yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceeac8525735900400c27/84636183a97ced24852576a20069961a!OpenDocument (accessed December 9, 2010).
34. Kentucky Division of Water. 2008. Integrated Report to Congress on Water Quality in Kentucky. http://www.water.ky.gov/sw/swmonitor/305b/ (accessed December 9, 2010).
35. Office of Surface Mining. 2008. *Final Environmental Impact Statement: Excess Spoil Minimization, Stream Buffer Zones.* Washington, DC. http://www.osmre.gov/aml/AML.shtm (accessed December 17, 2010).
36. U.S. Environmental Protection Agency. 2002. *Affected Environment and Consequences of Mountain-top Removal and Valley Fill Practices. Environmental Impact Statement*. Washington, DC http://www.epa.gov/region3/mtntop/pdf/III_affected-envt-consequences.pdf (accessed December 17, 2010).
37. Epstein, P.R., W. Moomaw & C. Walker. 2008. Healthy solutions for the low carbon economy: guidelines for investors, insurers, and policy makers. The Center for Health and the Global Environment. Harvard Medical School. Boston, MA.
38. Fox, J.F. & J.E. Campbell. 2010. Terrestrial carbon disturbance from mountaintop mining increases lifecycle emissions for clean coal. *Environ. Sci. Technol.* **44:** 2144–2149.
39. Groisman, P.Y., R.W. Knight, T.R. Karl, *et al.* 2004. Contemporary changes of the hydrological cycle over the contiguous United States: trends derived from in situ observations. *Journal of Hydrometeorology* **5:** 64–85.
40. Groisman, P.Y. & R.W. Knight. 2008. Prolonged dry episodes over the conterminous United States: new tendencies emerging during the last 40 years. *BAMS* **21:** 1850–1862.
41. Reinhart, N. 2010. Personal communication.
42. Intergovernmental Panel on Climate Change, United Nations Environment Programme. Technology and Economics Assessment Panel. 2005. IPCC special report on carbon dioxide capture and storage: summary for policymakers. 25 pp. Geneva, Switzerland. http://www.ipcc.ch/pdf/special-reports/srccs/srccs˙wholereport.pdf (accessed December 17, 2010).
43. Forster, P., V. Ramaswamy, P. Artaxo, *et al.* 2007. Changes in Atmospheric Constituents and in Radiative Forcing. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* 1–106.
44. West Virginia Department of Environmental Protection. 2010. http://www.dep.wv.gov/Pages/default.aspx (accessed December 9, 2010).
45. U.S. Environmental Protection Agency. 2010. EPA Facilities Registry. http://www.epa.gov/enviro/html/fii/fii_query_java.html (accessed December 9, 2010).
46. Dewan, S. 2009. Hundreds of coal ash dumps lack regulation. *New York Times*, January 6.
47. Environmental Integrity Project. 2009. Coming Clean: What the EPA Knows About the Dangers of Coal Ash. A Summary of the United States Environmental Protection Agency's 2007 Human and Ecological Risk

Assessment of Coal Combustion Wastes. http://www.environmentalintegrity.org/news_reports/news_09_05_07.php (accessed December 9, 2010).

48. Stout, B.M. & M.E. Cassidy. 2009. Personal communication.
49. Wheeling Jesuit University. 2006. Kentucky Coal Impoundment Location and Information System. http://www.coalimpoundment.org/locate/list.asp (accessed December 9, 2010).
50. Spath, P., M. Mann & D. Kerr. 1999. Life cycle assessment of coal-fired power production. Dept. of Energy, Oak Ridge, TN. http://www.nrel.gov/docs/fy99osti/25119.pdf (accessed December 9, 2010).
51. Stout, B.M. & M.E. Cassidy. 2006. Environmental and social-economic impacts of electrical generation from the fossil fuel cycle in the Mid-Atlantic Highlands (unpublished). 1–25.
52. U.S. Department of Energy, U.S. Department of Health and Human Services, U.S. Environmental Protection Agency. 1980. *Health effects of coal technologies: research needs*. Washington, DC. http://md1.csa.com/partners/viewrecord.php?requester=gs&collection=TRD&recid=20070430115163CE&q=Health+effects+of+coal+technologies%3A+research+needs.&uid=790182396&setcookie=yes (accessed December 17, 2010).
53. U.S. Department of Energy. 1986. *Effects of Coal Rank and the Chemical Composition and Toxicological Activity of Coal Liquefaction Materials*. Washington, DC.
54. U.S. Environmental Protection Agency. 2009. Clean Air Mercury Rule. http://www.epa.gov/mercuryrule/basic.htm (accessed December 9, 2010).
55. Kentucky Department of Fish and Wildlife Resources. 2009. Fish Consumption Advisories. http://www.fw.ky.gov/fishadvisory.asp (accessed December 9, 2010).
56. Clean Air Task Force. Power Plant Pollution Locator. 2010. http://www.catf.us/projects/power_sector/power_plant_emissions/pollution_locator/ (accessed December 9, 2010).
57. U.S. Environmental Protection Agency Clean Air Markets Division. 2004. Memorandum: Economic and energy analysis of the proposed interstate air quality rulemaking. http://www.epa.gov/cair/pdfs/tm0009.pdf (accessed December 17, 2010).
58. Keating, M., L. Evans, B. Dunham & J. Stant. 2009. Waste Deep: Filling Mines with Coal Ash is Profit for Industry, But Poison for People. http://www.earthjustice.org/news/press/2009/new-report-documents-unseen-threat-from-toxic-coal-ash (accessed December 9, 2010).
59. Koornneef, J., T. Van Keulen, A. Faaij & W. Turkenburg. 2008. Life cycle assessment of a pulverized coal power plant with post-combustion capture, transport and storage of CO2. *Int. J.Greenhouse Gas Control* **2:** 448–467.
60. Hendryx, M., K. O'Donnell & K. Horn. 2008. Lung cancer mortality is elevated in coal-mining areas of Appalachia. *Lung Cancer* **62:** 1–7.
61. Shiber, J. 2005. Arsenic in domestic well water and health in central Appalachia, USA. *Water, Air, Soil Pollut.* **160:** 327–341.
62. Hendryx, M. 2008. Mortality rates in Appalachian coal mining counties: 24 years behind the nation. *Environ. Justice* **1:** 5–11.
63. Ahern, M., M. Mullett, K. MacKay & C. Hamilton. 2010. Residence in coal-mining areas and low-birth-weight-outcomes. *Maternal Child Health J.* Epub ahead of print. doi: 10.1007/s10995-009-0555-1/ http://www.ncbi.nlm.nih.gov/pubmed/20091110 (accessed December 9, 2010).
64. Ahern, M., K. MacKay, D. Carpenter & M. Hendryx. Low birth weight and pre-term birth outcomes in coal mining areas of the United States. *J. Environ. Health* DOI: 10.1007/s10995-009-0555-1/ http://www.ncbi.nlm.nih.gov/pubmed/20091110 (accessed December 17, 2010).
65. Tyson, J.E. & S. Saigal. 2005. Outcomes for extremely low-birth-weight infants: disappointing news. *JAMA* **294:** 371–373.
66. Curhan, G. C. *et al*. 1996. Birth weight and adult hypertension, diabetes mellitus, and obesity in U.S. men. *Circulation* **94:** 3426–3250.
67. Hendryx, M. & M. Ahern. 2010. Appalachian Coal Mining & Human Health. *Spring 2010 Symposium, Mountaintop Coal Mining: Human Health and Ecological Concerns*. Presentation available upon request.
68. Hendryx, M. 2010. Personal communication.
69. Morse, J.C., B.P. Stark & W.P. McCafferty. 1993. Southern Appalachian streams at risk: implications for mayflies, stoneflies, caddisflies, and other aquatic biota. *Aqua. Conserv.: Marine Freshwater Ecosys.* **3**: 293–303.
70. Bragg, E.A. 1999. Civil Action No. 2:98–0636. United States District Court Southern District of West Virginia Civil Action No. 2:98–0636. United States District Court Southern District of West Virginia. http://www.publicjustice.net/Repository/Files/Bragg%20district%20court%20PI%20decision.pdf (accessed December 9, 2010).
71. Stout, B. & B. Wallace. 2005. A Survey of Eight Major Aquatic Insect Orders Associated with Small Headwater Streams Subject to Valley Fills from Mountaintop Mining. 1–13. http://www.epa.gov/region3/mtntop/pdf/appendices/d/StoutWallaceMacroinvertebrate.pdf (accessed December 17, 2010).
72. Gilbert, N. 2010. Mountain mining damages streams. *Nature* **466:** 806.
73. Kirk, E.J., R.A. Johnston & R. Maggard. 2010. An evaluation of the mayfly abundances and WV-SCI scores compared to levels of conductivity in several streams in southern West Virginia. *2010 West Virginia Surface Mine Drainage Task Force Symposium Papers*, Morgantown, WV, March 30-31. Conference: http://wvmdtaskforce.com/proceedings/2010.cfm. Paper: http://wvmdtaskforce.com/proceedings/10/Kirk-REIC-Argus-Mayfly-Conductivity-Paper.doc (accessed December 17, 2010).
74. Pond, G.J. 2010. Patterns of Ephemeroptera taxa loss in Appalachian headwater streams (Kentucky, USA). *Hydrobiologica* http://www.springerlink.com/content/b1w1153363782687/ (accessed December 17, 2010).

75. Pond, G.J., M. E. Passmore, F.A. Borsuk, *et al.* 2008. Downstream effects of mountaintop coal mining: comparing biological conditions using family- and genus-level macroinvertabrate bioassessment tools. *J. N. Am. Benthol. Soc.* **27:** 717–737.
76. Anon. 2007. Conservation: mines vs. mussels. *Nat. Geo. Magazine* **212**.
77. Merritt, R.W. & K.W. Cummins. 1996. *An Introduction to the Aquatic Insects of North America*. Kendall/Hunt Publishing Company. Dubuque, IA.
78. Palmer, M.A., E.S. Bernhardt, E.A. Chornesky, *et al.* 2005. Ecological science and sustainability for the 21st century. *Frontiers Ecol. Environ.* **3:** 4–11.
79. Hendryx, M. & K.J. Zullig. 2009. Higher coronary heart disease and heart attack morbidity in Appalachian coal mining regions. *Preven. Med.* **49:** 355–359.
80. U.S. Census Bureau. 2000. Net migration for the population 5 years and over for the United States, regions, states, counties, New England minor civil divisions, metropolitan areas, and Puerto Rico. Washington, DC.
81. U.S. Environmental Protection Agency. 2009. Emissions & Generation Resource Integrated Database. http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html (accessed December 9, 2010).
82. U.S. Environmental Protection Agency. 2009 National Emissions Inventory. http://www.epa.gov/oar/data/neidb.html (accessed December 9, 2010).
83. Pope, C.A. & D.W. Dockery. 2006. Health effects of fine particulate air pollution: lines that connect. *J. Air & Waste Manage. Assoc.* **56:** 709–742.
84. Levy, J. & J. Spengler. 2002. Modeling the benefits of power plant emission controls in Massachusetts. *J. Air & Waste Manage. Assoc.* **52:** 5–18.
85. Schneider, C. & M. Padian. 2004. *Dirty Air, Dirty Power: Mortality and Health Damage Due to Air Pollution from Power Plants*. Clean Air Task Force. Boston, MA.
86. Levy, J., J. Hammitt & J. Spengler. 2000. Estimating the mortality impacts of particulate matter: What can be learned from between-study variability? *Environ. Health Perspect.* **108:** 109–117.
87. O'Neill, M.S., A. Veves, A. Zanobetti, *et al.* 2005. Diabetes enhances vulnerability to particulate air pollution-associated impairment in vascular reactivity and endothelial function. *Circulation* **111:** 2913–2920.
88. Ritz, B., M. Wilhelm & Y. Zhao. 2006. Air pollution and infant death in southern California, 1989–2000. *Pediatrics* **118:** 493–502.
89. Levy, J.I., J.D. Spengler, D. Hlinka & D. Sullivan. 2000. *Estimated Public Health Impacts of Criteria Pollutant Air Emissions from the Salem Harbor and Brayton Point Power Plants*. Harvard School of Public Health. Boston, MA.
90. Schwartz, J., B. Coull, F. Laden & L. Ryan. 2007. The effect of dose and timing of dose on the association between airborne particles and survival. *Environ. Health Perspect.* **116:** 64–69.
91. Schwartz, J., 2010. Personal communication.
92. U.S. Environmental Protection Agency. 2009. National Ambient Air Quality Standards. http://www.epa.gov/air/criteria.html (accessed December 9, 2010).
93. Dockery, D.W. *et al.* 1993. An association between air pollution and mortality in six U.S. cities. *Engl. J. Med.* **329:** 1753–1759.
94. Roman, H., K.D. Walker, T.L. Walsh, *et al.* 2008. Expert judgment assessment of the mortality impact of changes in ambient fine particulate matter in the US. *Environ. Sci. Technol* **42:** 2268–2274.
95. Jaworski, N., R. Howarth & L. Hetling. 1997. Atmospheric deposition of nitrogen oxides onto the landscape contributes to coastal eutrophication in the northeast United States. *Environ. Sci. Tech.* **31:** 1995–2004.
96. Townsend, A.R., W. Howarth, F.A. Bazzaz, *et al.* 2003. Human health effects of a changing global nitrogen cycle. *Frontiers Ecol. Environ.* **1:** 240–246.
97. Heisler, J. *et al.* 2008. Eutrophication and harmful algal blooms: a scientific consensus. *Harmful Algae* **8:** 3–13.
98. Kirkpatrick, B., L.E. Fleming, D. Squicciarini, *et al.* 2004. Literature review of Florida red tide: implications for human health effects. *Harmful Algae* **3:** 99–115.
99. Shumway, S. 1990. A review of the effects of algal blooms on shellfish and aquaculture. *J. World Aquacul. Soc.* **21:** 65–104.
100. Wang, J. & J. Wu. 2009. Occurrence and potential risks of harmful algal blooms in the East China Sea. *Sci. Total Environ.* **407:** 4012–4021.
101. National Centers for Ocean Coastal Science. 2009. Economic Impacts of Harmful Algal Blooms. http://www.cop.noaa.gov/stressors/extremeevents/hab/current/econimpact_08.pdf (accessed December 9, 2010).
102. Hoagland, P. & S. Scatasta. 2006. *The Economic Effects of Harmful Algal Blooms*. Springer-Verlag. Dordrecht, the Netherlands.
103. Carlisle, E. 2009. The Gulf of Mexico Dead Zone and Red Tides. http://www.tulane.edu/~bfleury/envirobio/enviroweb/DeadZone.htm (accessed December 9, 2010).
104. Driscoll, C.T., G.B. Lawrence, A.J. Bulger, *et al.* 2001. Acid rain revisited: advances in scientific understanding since the passage of the 1970 and 1990 Clean Air Act Amendments. Hubbard Brook Research Foundation. Science Links' Publication. Vol. 1, no.1, Hanover, NH.
105. Yanai, R.D., T.G. Siccama, M.A. Arthur, *et al.* 1999. Accumulation and depletion of base cations in forest floors in the northeastern US. *Ecology* **80:** 2774–2787.
106. Banzhaf, H., D. Burtraw, D. Evans & A. Krupnick. 2004. Valuation of natural resource improvements in the Adirondacks. Resources for the Future, Washington, DC. 40 pp http://www.rff.org/rff/Documents/RFF-RPT-Adirondacks.pdf (accessed December 17, 2010).
107. Northeast States for Coordinated Air Use Management. 2003. Mercury emissions from coal-fired power plants: the case for regulatory action. NESCAUM, Boston, MA. *www.nescaum.org/documents/rpt031104mercury.pdf/* (accessed December 9, 2010).
108. Rice, G.E., J.K. Hammitt & J.S. Evans. 2010. A probabilistic characterization of the health benefits of reducing methyl mercury intake in the United States. *Environ. Sci. Tech.* **44:** 5216–5224.

109. IPCC. 2007. Climate Change 2007: Synthesis Report. Contribution of Work Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC. Geneva, Switzerland.
110. U.S. Environmental Protection Agency. 2008. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006. Washington, DC.
111. Hansen, J., M. Sato, P. Kharecha, *et al*. 2007. Climate change and trace gases. *Philos. Transact. A Math Phys Eng Sci.* **365:** 1925–1954.
112. Jacobson, M.Z. 2002. Control of fossil-fuel particulate black carbon and organic matter, possibly the most effective method of slowing global warming. *J. Geophys. Res.* **107:** (D19), 4410, doi:10.1029/2001JD001376, 22pp. [pp ACH 16-1 to 16-22]. http://www.stanford.edu/group/efmh/fossil/fossil.pdf (accessed December 9, 2010).
113. Ramanathan, V. & G. Carmichael. 2008. Global and regional climate changes due to black carbon. *Nat. Geosci.* **1:** 221–227.
114. Levitus, S., J. Antonov & T. Boyer. 2005. Warming of the world ocean, 1955–2003. *Geophys. Res. Lett.* **32:** L02604, doi:10.1029/2004GL021592.
115. Barnett, T., D.W. Pierce, K.M. AchutaRao, *et al*. 2005. Penetration of human-induced warming into the world's oceans. *Science* **309:** 284–287.
116. Epstein, P.R. & J.J. McCarthy. 2004. Assessing climate stability. *Bull. Am. Meteorological Soc.* **85:** 1863–1870.
117. IPCC. 2007. Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel of Climate Change*. Cambridge University Press. Cambridge, UK. 7–22.
118. Cooke, W., C. Liousse, H. Cachier & J. Feichter. 1999. Construction of a 1× 1 fossil fuel emission data set for carbonaceous aerosol and implementation and radiative impact in the ECHAM4 model. *J. Geophys. Res.* **104:** 22137–22162.
119. P.R. Epstein, P.R. & E. Mills (Eds.) 2005. *Climate Change Futures: Health, Ecological and Economic Dimensions, Center for Health and the Global Environment*, Harvard Medical School, Boston, MA.
120. Thompson, C. 2010. Disaster capitalism. *Mother Jones* July/Aug. 2010.
121. Stern, N. 2003. *Stern Review on the Economics of Climate Change*. Cambridge University Press. Cambridge, UK. www.nescaum.org/documents/rpt031104mercury.pdf/ (accessed December 17, 2010).
122. Haszeldine, R. 2009. Carbon capture and storage: how green can black be? *Science* **325:** 1647–1652.
123. General Accounting Office. 2008. *Climate Change: Federal Actions Will Greatly Affect the Viability of Carbon Capture and Storage as a Key Mitigation Option*. Washington, DC.
124. Renard, F., E. Gundersen, R. Hellmann, *et al*. 2005. Numerical modeling of the effect of carbon dioxide sequestration on the rate of pressure solution creep in limestone: Preliminary results. *Oil & Gas Sci. Tech.* **60:** 381–399.
125. KNBC. 2006. Coroner: carbon dioxide killed men on mammoth mountain. http://www.knbc.com/news/8516441/detail.html (accessed December 9, 2010).
126. Konty, M.F. & J. Bailey. 2009. The impact of coal on the Kentucky State Budget. http://www.maced.org/coal/ (accessed December 9, 2010).
127. Energy Information Administration. 2008. Federal Financial Interventions and Subsidies in Energy Markets 2007. http://www.eia.doe.gov/oiaf/servicerpt/subsidy2/index.html (accessed December 9, 2010).
128. Environmental Law Institute. 2009. Estimating U.S. Government subsidies to energy sources: 2002–2008. 1–37. Washington, DC. http://www.eli.org/Program_Areas/innovation_governance_energy.cfm (accessed December 17, 2010).
129. Office of Surface Mining Reclamation and Enforcement. 2009. Estimating U.S. Government Subsidies to Energy Sources: 2002–2008. http://www.osmre.gov/aml/AML.shtm (accessed December 9, 2010).
130. Lockie, S., M. Franettovich, V. Petkova-Timmer, *et al*. 2009. Coal mining and the resource community cycle: a longitudinal assessment of the social impacts of the Coppabella coal mine. *Environ. Impact Asses.* **29:** 330–339.
131. Wood, L.E. 2005. Trends in national and regional economic distress: 1960–2000. http://www.arc.gov/assets/research˙reports/TrendsinNationalandRegionalEconomicDistress1960to2000.pdf (accessed December 17, 2010).
132. Marmot M. & R.G. Wilkinson. Eds. 2006. *Social Determinants of Health.* 2nd ed. Oxford University Press. Oxford, UK.

The Social Cost of Coal: Implications for the World Bank

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Summary for Policymakers

The World Bank is considering adopting a new energy strategy that would define the institution's goals for energy sector lending and investments. Like other development assistance organizations, the World Bank needs to make sure that its energy portfolio helps advance a variety of goals, including economic growth, poverty alleviation, social justice and climate protection.   The World Bank is considering what role coal projects should have in its lending strategy. This paper summarizes the state of knowledge on the social cost of coal-fired power plants in an effort to help inform ongoing policy discussions.

Although superficial analyses often find that coal-fired power is the cheapest source of energy, these analyses fail to account for the myriad costs of coal-fired electricity for society. Health impacts remove productive citizens from the work force and shift spending away from industries and education. Water pollution creates further health problems and makes agriculture more expensive, raising the cost of living and reducing international competitiveness. The adverse impacts of climate pollution from coal plants, such as floods, storms and droughts, carry significant economic and social costs.

Findings

The results of a number of independent economic studies confirm that these "external" costs (faced by society and not the facility owners) make coal-fired power one of the most expensive forms of electricity generation (see Table 1). As shown below, nuclear, natural gas, wind, and biomass cost between $52/MWh and $88/MWh, while pulverized coal costs roughly $100/MWh.

Table 1: Social costs of electricity generation (2010$/MWh)

	Coal		**Lower Emissions**		**Renewables**		
	PC	**IGCC**	**Nuclear**	**Natural Gas**	**Wind**	**Solar**	**Biomass**
Explicit Costs	$41	$77	$41	$53	$70	$154	$78
External Costs	$58	$57	$11	$30	$2	$6	$11
Total	$99	$134	$52	$83	$72	$160	$88

The external costs of coal-fired power, including pulmonary disease, mercury poising, and premature death, have a significant effect on the countries that bear them. The choice to build a 4,000 MW coal power plant instead of a comparable nuclear, natural gas, wind, or biomass plant, even taking into account the coal plant's lower construction and operations costs, results in $319 to $1,414 million additional social costs (see Table 2). For this hypothetical single coal plant, additional expected costs would include approximately $370 million in health costs in mining communities, $940 million in air pollution costs, and $108 to $320 million in climate change costs.

Table 2: Social cost tradeoffs of Pulverized Coal versus other generation sources (Million 2010$)

	Coal	Nuclear	Natural Gas	Wind	Biomass
Explicit Costs	$1,221	$1,221	$1,592	$2,089	$2,315
External Cost					
Health in Mining Communities	$374	-	-	-	-
Air Pollutants from Combustion	$937	-	-	-	-
Effects of Mercury	$28	-	-	-	-
Climate Change Impacts	$320	-	$211	-	-
Other Externalities	$69	$314	$668	$63	$314
Total	$1,728	$314	$880	$63	$314
Social Costs	$2,949	$1,535	$2,472	$2,152	$2,629
Additional Social Costs of PC		+$1,414	+$477	+$797	+$319

IMPLICATIONS FOR THE WORLD BANK

The implication of this analysis is that the World Bank's choice to fund a new coal power plant over an equivalent cleaner nuclear, natural gas, wind, or biomass power plant significantly burdens recipient countries and the poor. The World Bank should redirect its funding to cleaner generation sources that avoid such great costs for the recipient countries.

The World Bank's own operational policies require it, before financing any project, to determine whether a given investment opportunity "creates more net benefits to the economy than other mutually exclusive options for the use of the resources in question."[1] The research summarized here demonstrates that a pulverized coal power plant, the most common type of new coal generation facility, does not meet this standard.

[1] World Bank. Operational Policy 10.04.

TECHNICAL BACKGROUND NOTE

The World Bank is considering adopting a new energy strategy, including determining what role coal projects should have in its lending strategy. Although superficial analyses often find that coal-fired power is the cheapest source of energy, these analyses fail to account for the myriad costs of coal-fired electricity for society. This technical note draws on other independent economic studies to estimate the social cost of electricity generation from a new coal-fired power plant in comparison to other potential sources of generation in various countries around the world.

INTRODUCTION

The World Bank is a major financier of power plants and other vital infrastructure around the world. In determining which projects to finance, the World Bank follows Operational Policy (OP) 10.04, which requires economic evaluation of investment projects to "determine whether the project creates more net benefits to the economy than other mutually exclusive options for the use of the resources in question" (World Bank 1994). This language echoes the standard economic logic, that the social welfare maximizing option should achieve more positive social benefits than any other options. The mandate ensures that the World Bank only finances the most socially beneficial projects.

In determining the net benefits to the economy created by each option, OP 10.04 directs the World Bank to calculate, to the extent possible, both the explicit costs (the monetary cost paid by the owner of the project) and the external costs (costs not paid by the owner of the project but borne by society). In the case of a coal power plant, the explicit costs would include, for example, the cost of physical materials and fuel for the plant, while the external costs would include among many things the health effects of air emissions and water pollution by the plant. The sum of these two costs represents the full social cost of the generation source. As the benefits of electricity are uniform between sources, meaning a unit of electricity creates the same amount of social benefits regardless the fuel from which it is generated, the generation source with the least social cost has the greatest social benefits.

This study draws together available data from the medical and economic literatures to calculate the social cost of electricity generation from coal and other potential generation sources. We review the seven most common sources of generation, including two forms of coal generation (pulverized coal (PC) and integrated gasification combined cycle (IGCC)), two forms of lower emissions generation (natural gas combined cycle and a nuclear pressurized water reactor), and three forms of renewable generation (onshore wind turbines, solar thermal, and solid biomass).[1]

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[1] We did not examine a natural gas combustion turbine as it is generally a source of peak load generation (a "peaker") and thus is not a viable substitute for a base load pulverized coal power plant.

The study finds that generation from a pulverized coal (PC) power plant, the most common form of coal generation, is often among the cheapest in terms of explicit costs but the most expensive in terms of external costs and, as a result, not the least expensive in terms of social cost. The results of this study suggest that the World Bank should not finance pulverized coal power plants.

EXPLICIT COSTS

The explicit costs of electricity generation, as mentioned above, represent the costs paid by the power plant owner to build the facility and generate electricity. The major sources of costs include capital costs (the cost of building the plant itself), fixed and variable operations and maintenance (O&M) costs, and the cost of fuel (which is zero for renewable power plants). Costs are generally calculated on a per Megawatt-hour (MWh) or "levelized" basis in order to enable comparison between sources of generation. The resulting per MWh cost is known as the levelized cost of energy (LCOE).

Table 1: Explicit costs of Electricity Generation (LCOE, 2010$/MWh)[2]

	Coal		**Lower Emissions**		**Renewables**		
Data Source	**PC**	**IGCC**	**Nuclear**	**Natural Gas**	**Wind**	**Solar**	**Biomass**
IEA 2010							
OECD	$81	$75	$57	$89	$108	$211	$54
Non-OECD	$41	-	$41	$53	$70	-	$78
Industry	$62	-	$54	$75	$69	$154	-
EIA 2010	$96	$112	$116	$64	$99	$317	$114
MIT 2003	$52	-	$82	$50	-	-	-
CERI 2004	$50	-	$68	$63	-	-	-
RAE 2004	$56	$69	$49	$48	$115	-	$145
University of Chicago 2004	$44	-	$71	$48	-	-	-
IEA/NEA 2005	$57	$55	$59	$62	$114	$161	$90
OK DTI 2006	$58	$62	$79	$73	$170	-	-
MIT 2007	$55	$59	-	-	-	-	-
CBO 2008	$62	-	$81	$64	-	-	-
EC 2008	$65	$71	$97	$79	$132	$301	$197
EPRI 2008	$71	$77	$81	$88	$101	$194	$88
House of Lords 2008	$91	-	$100	$86	$161	-	$199
MIT 2009	$69	-	$93	$72	-	-	-

In our study, we examine many estimates of the explicit LCOEs for new generation. The first source, labeled as International Energy Agency (IEA 2010), represents an average calculated by the author of costs in OECD and non-OECD countries and from industry estimates con-

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[2] All costs converted into 2010$ using the Consumer Price Index for All Urban Consumers published by the US Bureau of Labor Statistics (BLS 2011). IEA estimates assume a 5% cost of capital. Other estimates assume various costs of capital.

tained in the IEA report. The second source, the Energy Information Agency (EIA 2010), applies only to the United States. The remaining sources are taken from a literature review of other external cost estimates prepared by the IEA (IEA 2010). The results of the first two sources and the various studies from the literature review are shown in Table 1.

We prefer the non-OECD estimates within the first source as the calculated averages are based on non-OECD data, which is relevant because the World Bank does not fund as many projects in OECD countries as in non-OECD countries and we do not believe that OECD cost estimates are representative of explicit costs in non-OECD countries (as demonstrated by comparing the OECD and non-OECD estimates). We also prefer the non-OECD costs because they do not contain any assumed carbon cost (the IEA adds a carbon cost to all OECD and industrial estimates from OECD countries which cannot be factored out).[3] The two exceptions to this rule are the estimate for solar, taken from the industry estimate in IEA 2010 as no non-OECD estimate is available, and IGCC, taken from the EPRI 2008 study as no non -OECD estimate is available and the other IEA 2010 estimates include the price of carbon.

Table 1 shows that generation from a pulverized coal plant is among the most cost-effective in terms of explicit costs.

External Costs

The external costs of power generation, also discussed above, represent the costs not paid by the owner of the generation facility but borne by society. By definition, these costs are not taken into account by the owner in deciding whether to build a new power plant. The major external costs from power generation include negative health impacts from air emissions, water pollution from coal mining and oil and gas extraction, and climate change impacts from greenhouse gas emissions.

The external cost of power generation must include all external costs attributable to generating electricity from the given generation source. Economists refer to this as the “lifecycle” external costs, or the external costs resulting from all stages of the production process. In the case of electricity generation from coal power plants, the full lifecycle includes coal mining, transportation of coal to the power plant, construction of the power plant and related infrastructure, generation of electricity from the power plant, and disposal of waste products, such as coal ash. The idea is to capture all external costs attributable to generating electricity from a given source.

In this study, we examined the widely-considered best estimates of the lifecycle external cost estimates for generation from a new power plant (Burtraw et al Forthcoming). The results of these studies, converted to 2010$/MWh, are shown in Table 2. Results for RFF/ORNL 1995, Rowe et al 1995, ExternE 2005, and NRC 2010 taken from Burtraw et al (Forthcoming). The results for RFF/ORNL 1995, Rowe et al 1995, and ExternE 2005 do not include climate change impacts, which are estimate to be $21/mt CO2e or about $18 /MWh for a pulverized coal power plant (with a heat rate of 9,200 btu/kwh) or about $7/MWh for a natural gas

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[3] For IGCC, we use the explicit costs from EPRI 2008 as the IEA 2010 OECD estimate includes the cost of carbon and as the EIA cost estimate falls at the upper end of the range of estimates.

combined cycle (with a heat rate of 6,700 btu/kwh) (Greenstone et al 2010).

The studies provide a broad range of estimates of the social cost of coal generation. We prefer the estimates of Rafaj and Kypreos 2007 for a variety of reasons. First, the results are highly credible. The estimates are based on the ExternE project (whose results are also included in the table), a large, multi-year, peer-reviewed study of lifecycle impacts of electricity generation. Further, the results are used in the MARKAL model, a computable general equilibrium model of the world economy managed by the IEA. Second, the results are globally applicable. Rafaj and Kypreos adjust the ExternE results to create a global estimate, for use in the MARKAL model. Third, the results include estimates for all the potential generation sources we review, ensuring a common methodological approach with the coal social cost estimate.

Table 2: External costs of electricity generation (2010$/MWh)[4]

	Coal		**Lower Emissions**		**Renewables**		
Data Source	**PC**	**IGCC**	**Nuclear**	**Natural Gas**	**Wind**	**Solar**	**Biomass**
RFF / ORNL 1995	$2.3	-	$0.5	$0.4	-	-	$3.0
Rowe et al 1995	$1.3-$4.1	-	$0.2	$0.3	$0.0	-	$4.8
ExternE 2005	$27-$202	-	$3.4-$9.4	$13.4-$53.8	$0-$3.4	-	$0-$67
NRC 2010	$2-$126	-	-	$0-$5.8	-	-	-
Epstein et al 2011	$180.7	-	-	-	-	-	-
Rafaj and Kypreos 2007	$58.0	$57.0	$10.5	$29.5	$2.1	$6.3	$10.5

As shown in Table 2, electricity generation from a pulverized cost power plant is the most costly in terms of external costs. We specifically use the Rafaj and Kypreos estimate for the social cost of a coal plant with emissions controls for criterion pollutants, such as scrubbers for SO2 and selective catalytic reduction (SCR) for NOx. This is a conservative assumption that likely biases downwards the social cost of coal as many coal plants do not have such emissions controls and the Rafaj and Kypreos estimate for the social cost of a coal plant without such controls is significantly higher ($222 / MWh).

SOCIAL COSTS

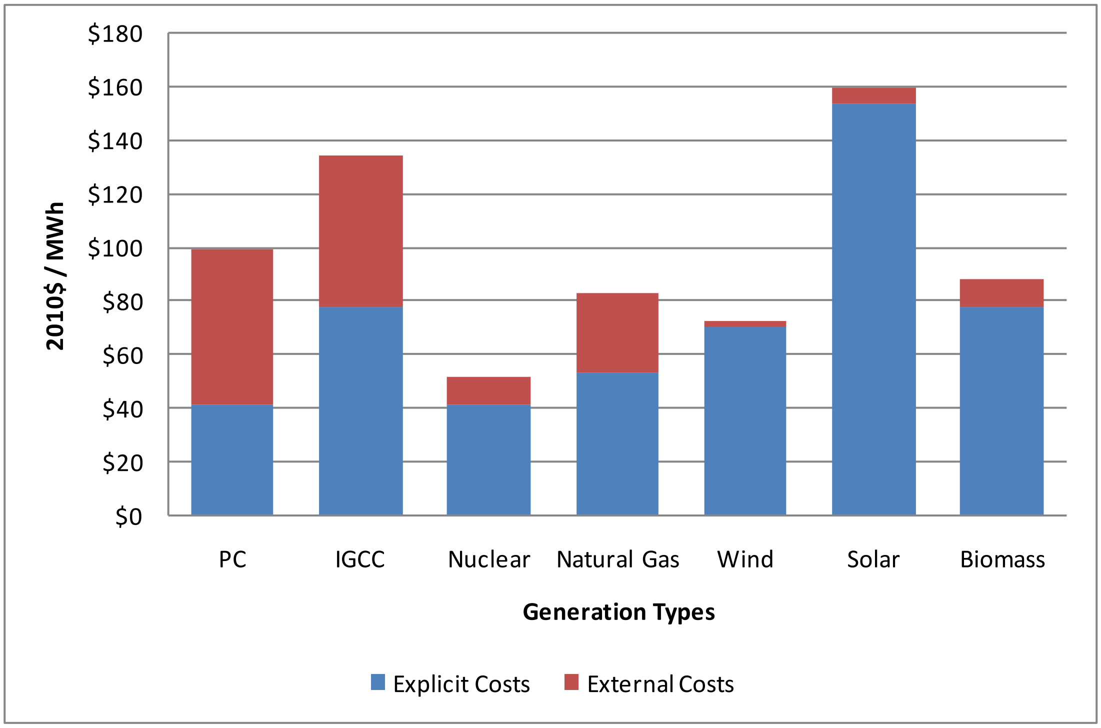
Using our preferred estimates for explicit and external costs, we calculate the social cost of electricity generation from our set of generation sources, including a pulverized coal power plant. The results of this calculation are shown in Table 3 and Figure 1.

Table 3: Social costs of electricity generation (2010$/MWh)

	Coal		**Lower Emissions**		**Renewables**		
	PC	**IGCC**	**Nuclear**	**Natural Gas**	**Wind**	**Solar**	**Biomass**
Explicit Costs	$41	$77	$41	$53	$70	$154	$78
External Costs	$58	$57	$11	$30	$2	$6	$11
Total	$99	$134	$52	$83	$72	$160	$88

[4] All costs converted from local currencies to US dollars using prevailing exchange rates at the time of the calculation, namely 0.1549 RMB to USD and 1.4521 EUR to USD (Google 2011a and Google 2011b). Foreign currents converted into 2010 equivalents using historical inflation rates for from the International Monetary Fund (IMF), World Economic Outlook Database (IMF 2011).

Figure 1: Social costs of electricity generation (2010$/MWh)



As Table 3 and Figure 1 demonstrate, electricity generation from a pulverized coal power plant is not the most cost-effective in terms of social cost.

SENSITIVITY ANALYSIS

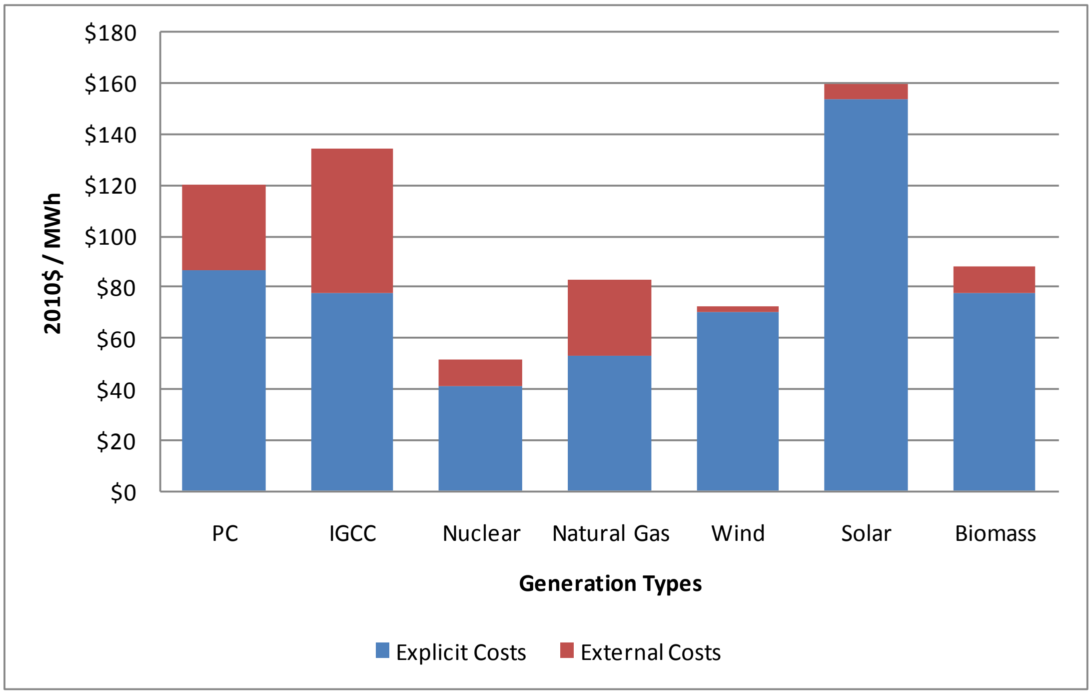
We conduct one sensitivity analysis to demonstrate the robustness of our results to alternative coal plant configurations. Specifically, we replace the previous estimate for the social cost of a Pulverized Coal plant with one for the most efficient pulverized coal plant (ultra-supercritical) with the addition of carbon capture and Sequestration (CCS). The purpose of this sensitivity analysis is to demonstrate that even with high efficiency and social cost of coal, the pulverized coal plant does not have the lowest social cost.

For explicit costs, we use the IEA 2010 estimate for an ultra-supercritical Pulverized Coal Plant with Carbon Capture and Sequestration. For external costs, we use the external cost estimate for a Pulverized Coal plant with a CCS system from Rafaj and Kypreos 2007. The sensitivity case social cost results are shown in Figure 2 and Table 5.

Table 5: Social Costs of Electricity Generation – all available coal emissions controls for Pulverized Coal (2010$/MWh)

	Coal		**Lower Emissions**		**Renewables**		
	PC	**IGCC**	**Nuclear**	**Natural Gas**	**Wind**	**Solar**	**Biomass**
Explicit Costs	$87	$77	$41	$53	$70	$154	$78
External Costs	$34	$57	$11	$30	$2	$6	$11
Total	$121	$134	$52	$83	$72	$160	$88

Figure 2: Social costs of Electricity Generation – all available coal emissions controls for Pulverized Coal (2010$/MWh)



Although the addition of the controls reduces external costs, it drastically increases explicit costs. As a result, pulverized coal is still not the most cost-effective source of electricity.

DISAGGREGATION OF EXTERNAL COSTS

We also disaggregate the external costs of a coal plant and compare the disaggregated external costs to the external costs of other possible generation sources. We disaggregate and compare the external costs to contextualize and provide more clarity on the external costs.

We start with the same external costs used in the base case provided by Rafaj and Kypreos 2007. This estimate, however, does not provide a disaggregation of the components of the external costs. As such, we take the disaggregated external costs provided by Epstein et al 2011 to calculate the share of total external costs represented by each component. Although the Epstein et al estimate is calculated for the U.S. only, we assumed that the shares of external cost components should be similar across countries. We then apply these shares to the Rafaj and Kypreos 2007 external cost estimate, generating the coal results shown in Table 6.

Table 6: Disaggregation and comparison of the external cost of electricity generation for Pulverized Coal versus other generation sources (Million 2010$)

	Coal	Nuclear	Natural Gas	Wind	Biomass
Explicit Costs	$1,221	$1,221	$1,592	$2,089	$2,315
External Cost					
Health in Mining Communities	$374	-	-	-	-
Air Pollutants from Combustion	$937	-	-	-	-
Effects of Mercury	$28	-	-	-	-
Climate Change Impacts	$320	-	$211	-	-
Other Externalities	$69	$314	$668	$63	$314
Total	$1,728	$314	$880	$63	$314
Social Costs	$2,949	$1,535	$2,472	$2,152	$2,629
Additional Social Costs of PC		+$1,414	+$477	+$797	+$319

For the purposes of this table, we specifically calculate disaggregated external costs for the four most important components according to Epstein et al and group all other components under the "Other" category. As no source we found provides a comparable disaggregation of external costs for the other sources (nuclear, natural gas, wind, and biomass), we could not disaggregate the external costs for the other generation sources and included all of their external costs except for climate change impacts within the other category. For climate change impacts from natural gas (nuclear plants, wind, and biomass are assumed to generate no net direct CO2 emissions), we calculated the emissions rate of a natural gas combined cycle and multiplied it by the social cost of coal calculated by Greenstone et al 2010. To calculate total costs of a representative plant, we multiply all the $/MWh external costs by 4,000 MW, the approximate capacity of a recent coal power plant partially funded by the World Bank in South Africa (World Bank 2010).

References

Bureau of Labor Statistics (BLS) (2011). "CPI Detailed Report: Data for May 2011." http://www.bls.gov/cpi/cpid1105.pdf. Accessed on July 4, 2011.

Burtraw, Dallas, Alan Krupnick, and Gabriel Sampson. "True Cost of Electric Power." Forthcoming.

Energy Information Agency (EIA) (2010). "Assumptions to America's Energy Outlook 2010." 92. http://www.eia.gov/oiaf/aeo/assumption/index.html

European Commission (ExternE) (2005). Externalitites of Energy: Methodology 2—5 Update. P Bickel and R. Friedrich, Luxembourg.

Epstein, Pual R., Jonathan J. Buonocore, Kevin Eckerle, Michael Hendryx, Benjamin M. Stout III, Richard Heinberg, Richard W. Clapp, Beverly May, Nancy L. Reinhart, Melissa M. Ahern, Samir K. Doshi, Leslie Glustrom. (2011). "Fully cost accounting for the life cycle of coal." Annals of the New York Academy of Sciences 1219: 73-98.

Google (2011a). Search of term "convert RMB to USD." Accessed on July 4, 2011.

Google (2011b). Search of term "convert EUR to USD." Accessed on July 4, 2011.

Greenstone, Michael, Elizabeth Kopits, and Ann Wolverton (2011). "Estimation the Social Cost of Carbon for Use in U.S. Federal Rulemakings: A Summary and Interpretation." NBER Working Paper Series. Working Paper 16913. http://www.nber.org/papers/w16913

International Energy Agency (IEA) (2010). "Projected Costs of Generating Electricity 2010 Edition." http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2207

International Monetary Fund (IMF) (2011). World Economic Outlook Database. April 2011. Accessed on June 26, 2010. http://www.imf.org/external/pubs/ft/weo/2011/01/weodata/index.aspx

National Research Council. (2010). *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. Washington: National Academies Press.

Rafaj, Peter and Socrates Kypreos (2007). "Internalisation of external cost in the power generation sector: Analysis with Global Multi-regional MARKAL Model." Energy Policy. 35. 2. February. 828-843. ftp://124.42.15.59/ck/2011-02/165/009/226/759/Internalisation%20of%20external%20cost%20in%20the%20power%20generation%20sector%20Analysis%20with%20Global%20Multi-regional%20MARKAL%20model.pdf

World Bank 1994. "Operational Policy 10.04, Economic Evaluation of Investment Operations." September 1994. http://web.worldbank.org/WBSITE/EXTERNAL/PROJECTS/EXTPOLICIES/ EXTOPMANUAL/0,,contentMDK:20064625~menuPK:4564185~pagePK:64709096~piPK:64709108~theSitePK:502184,00.html.

Some Comments on the Draft NSW Renewable Energy Action Plan

Northern Illawarra Sustainability Alliance

Note: This document has not been thoroughly proof read.

Contents

General Remarks

The need to reduce carbon emissions is clear and, as discussed below, the window of opportunity within which to take the required action without incurring significant additional costs is closing rapidly.

The draft Renewable Energy Action Plan (dREAP) sketches a commendable step towards a low carbon economy. The dREAP is however undermined by the policies and determined preferences of the present Government. As discussed below, the Premier has a publically stated a disdain for wind farms[1] and the Government's draft Wind Farm Guidelines are notably demanding.[2,3] This is regrettable, as wind farms are a source of electricity that can be rapidly deployed at relatively low cost, and use a 'feedstock' that is literally freely available. Wind power lowers electricity prices, benefiting domestic and business consumes and increasing the State's competitiveness.[20]

While surveys show a minority in the community regard the amenity impacts of wind farms as undesirable[56], their health, environmental and amenity impacts pale in comparison to those of a coal mine. While for some wind farms may have a greater visual impact than a coal seam gas (CSG) field, they do not have a potential to impact on aquifers, do not produce large volumes of salt laden water, will not cause earthquakes or subsidence, will not release methane and do not produce carbon dioxide and, as mentioned, the energy source for wind generated electricity is free.

Contradicting the intent of the dREAP, the NSW Government is opposed to the national renewable energy target (RET)[4] and earlier this month the Premier wrote to the Prime Minister expressing his opposition to the large scale renewable energy target (LRET)[5], expressing concern at the prospect of more wind turbines and suggesting that it would increase electricity prices.

The Minister for Resources and Energy Chris Hartcher has firmly committed the Government to the extraction and utilisation the State's coal seam gas resources.[6] The Minister has stated that renewable energy technologies are not yet capable of replacing coal or gas fuelled generators, being comparatively expensive and unable to provide baseload electricity. On both counts, the Minister's comments are out of touch with recent developments; costs have fallen sharply[9] and there has been shift away from the conventional view of baseload power.[13(f),48,49]

The dREAP commits the Government to a least cost path to support the national goal of 20% renewable energy by 2020, while maximising investment benefits for NSW. Figure 5 in the dREAP suggests NSW currently has 5,408 MW if installed renewable energy capacity and 2012 Australian Energy Market Operator (AEMO) figures[7] indicate NSW has a total generating capacity of approximately 17,000 MW. On that basis then renewable energy sources currently provide some 32% of the total generating capacity in NSW, and no further investment in renewable energy is necessary if the national goal is for each state to reach a level of 20% by 2020.

The contribution from hydroelectricity in Figure 5 suggests a capacity of some 4,600 MW or 27% of the capacity from all sources. The Figure 5 capacity of 4,600 MW is significantly more than the 2,837 MW given in the 2012 AEMO tally (2619 MW scheduled and 218 non-scheduled; 16.7% of capacity from all sources) for hydroelectricity in NSW. Adjusting the total capacity for this difference indicates a renewable energy supply of 3,645 MW, which is 21% of the total and so still more than the national goal for 2020. As Table 1 below suggests however, competing water demands limit the operational capacity for hydroelectricity. In the first quarter of 2012 hydro provided only 4% of the State's electricity.

In the first quarter of 2012 hydro provided only 4% of the State's electricity.

The perspective given in Figure 5 of the dREAP suggests NSW effectively already has a renewable capacity above 20% and there is then no need to include any provision for financial incentives to attract additional renewable energy investment in NSW; the dREAP makes no such commitment. In contrast the fossil fuel industry enjoys supporting subsidies and the NSW Government is considering incentives for the coal seam gas industry.

On releasing the dREAP Minister Hartcher stated that under the plan the State's wind farm and solar PV capacity would triple by 2020.[8] The current AEMO figures give a current NSW wind farm capacity of 281 MW, suggesting tripling the capacity would provide 843 MW by 2020. AEMO forecasts a maximum growth of 1.6% to 2020, indicating a rise in total capacity from around from 17,000 MW to 17,272 MW. Wind capacity would then rise from 1.6% of current capacity to 4.8% by 2020. Currently there are proposals for approximately 2000 MW of new wind capacity before the Government - significantly more than the Minister expects by 2020. Perhaps explaining the discrepancy, the Minister responsible for the NSW draft Wind Farm Guidelines, the Minister for Planning and Infrastructure Brad Hazzard, is reported to have commented that 13 of 17 proposals before the Government will not satisfy the draft guidelines.[2] Given the views of the Premier and Minister Hazzard, its unlikely wind generated capacity in NSW will triple by 2020 as a result of policy settings from the current Government.

Government policy will ensure that wind farms will not undermine its determination to exploit coal seam gas which, while strongly opposed in the communities where CSG fields may be developed, is very attractive to the Government as a source of royalty revenue - as is coal. Renewable energy yields no royalties. The Government has, it seems, opted to set aside the direct and indirect cost, health and environmental benefits of renewable energy in favour of continued revenue from fossil fuels. There is however a rapidly emerging trend that may well undermine the Government's approach to electricity generation. The cost of solar PV has fallen 45% in the past year and is expected to continue with every doubling of manufacturing resulting in a 24 per cent cost reduction.[9(b),10]Solar PV and wind will be cheaper than coal gas within the next decade and with generation already below grid parity, solar PV is an increasingly attractive option for consumers.

The cost of solar PV has fallen 45% in the past year and is expected to continue with every doubling of manufacturing resulting in a 24 per cent cost reduction.[9(b),10]

In early October Deutsche Bank analyst Vishal Shah reported that the cost of utility-scale solar is coming down so quickly that developers are in a position to sign power purchase agreements of less than 10c/kWh - this was not expected to occur until closer to the end of the decade.[11].In fact grid parity and utility cost comparisons are unlikely to be the key concern for consumers; rooftop solar

PV is already a cost effective option. The BNEF paper suggests 'grid parity' is a misleading term that disguises the fact that many PV applications are not competing against wholesale generation but are instead competing against the delivered price of electricity through the grid.[9,53(a)] That is, 'socket-parity' is of more importance to consumers than grid-parity.

The 2012 AEMO report on roof-top solar PV projects NSW growth to 3000 MW of capacity by 2020 and this estimate of a tenfold increase relative to current installations may prove to be conservative. Unless the NSW Government discourages the take-up of solar PV, as it has done for wind power, this will happen irrespective of the Renewable Energy Action Plan and Minister Hartcher's associated forecast of a tripling of solar and wind generated electricity by 2020.

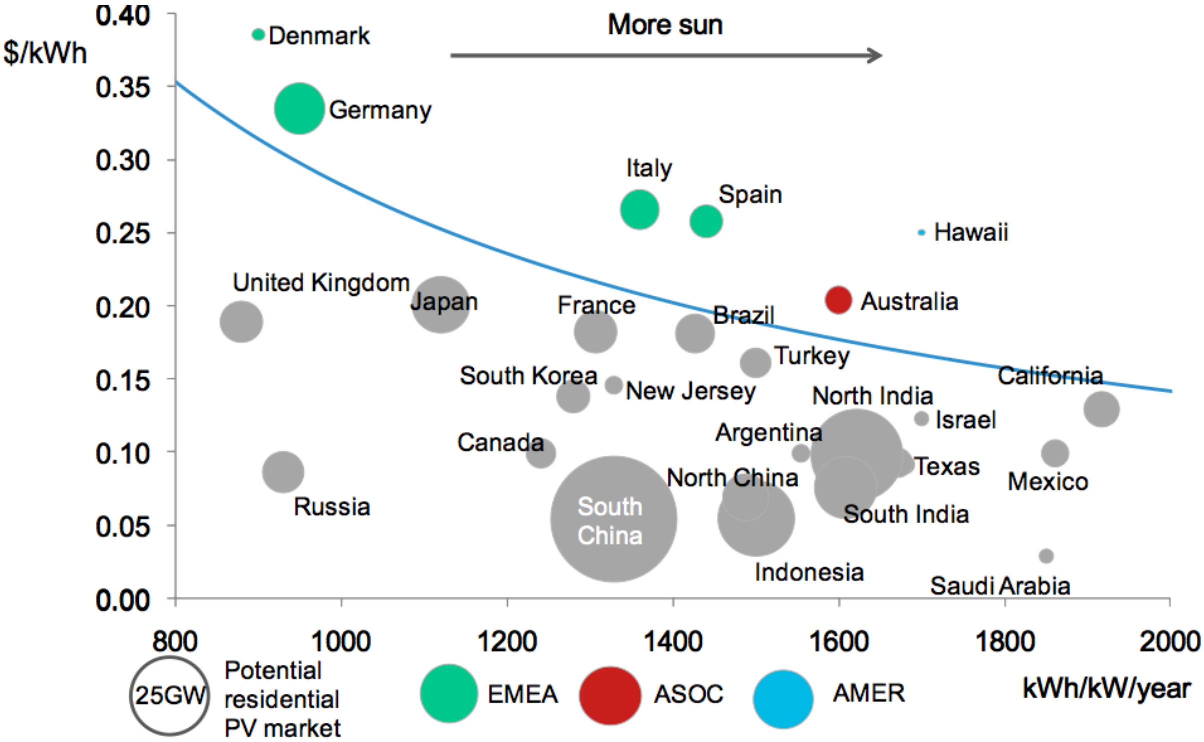
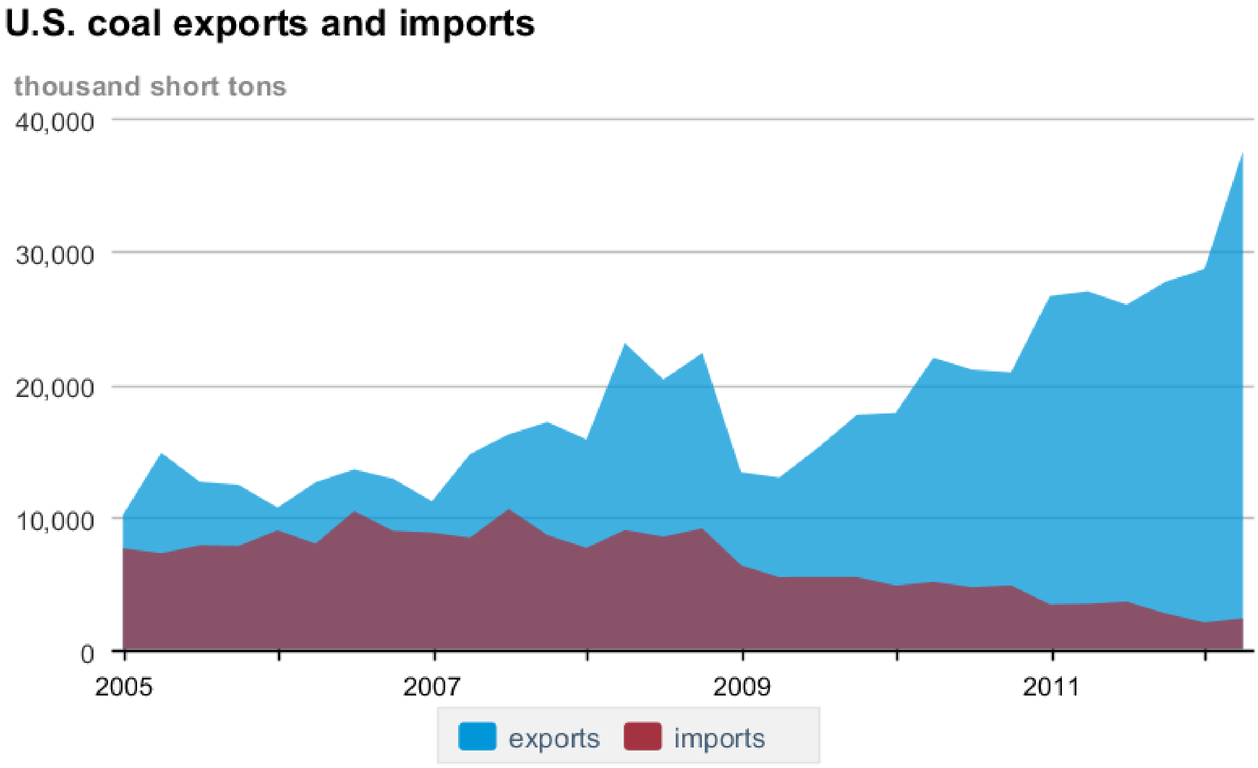


Figure 1. BNEF depiction of the levelised cost of solar PV in the retail market in 2012, compared with the retail price of electricity. Countries are ranked according to the amount of solar irradiation (right axis) and the size of PV market (circles). All countries above the blue line are at or better than price parity.[9] The BNEF projection for 2015 shows a significant increase in countries above the parity curve.

The BNEF paper and analysis by Deutsche bank suggests the rapid fall in cost of solar PV will have a similar impact on electricity grids to that of mobile phones on land lines.[12]

Unless the NSW Government introduces disincentives, the sharp cost decline and consequentially increasing take-up of solar PV will undermine the fossil fuel based royalty revenue model currently favoured by the Government. Consumers will choose to forgo market driven electricity price rises in gas fuelled generation[55] and price rises in distribution networks, and instead install roof-top solar PV systems; its already happening.[9(c)] Energy consultants AECOM argues that relying on natural gas for domestic electricity production could see consumer electricity prices soar as a result of exposure to volatile international gas markets.[55(a)] The gas infrastructure the Government hopes to see rapidly installed in NSW would be expected to operate for at least 20 years, yet it’s likely to become uncompetitive within a decade. The use of gas on the east coast of Australia declined in 2012, in part because of the growth in wind generation and solar PV installations.[19]

Economics are already catching up with coal.[13] A tripling of wind power[13(g)] and the now well established transition to gas in the US has contributed to a decline in the use of coal with the 2012 having the lowest level of use in 25 years, while US exports have increased sharply[13(a); Fig. 2], pushing down the international market price of the commodity.[13(f,h,i)]] This trend is already shaping coal investment in Australia. Carbon dioxide emission and other environmental and health impacts additionally make coal an untenable investment option. Carbon capture and storage is an unrealistic and costly panacea.[14] The downward trend in coal prices, coupled with the falling price of renewable energy, will continue to erode the value of the State owned coal fired power stations in NSW.



Source: U.S. Energy Information Administration

Figure 2. US coal export and import trends.[13(a)]

Given current Government policy and preferences in favour of fossil fuel use, which enjoys significant subsidy support, the ‘incentive free’ dREAP will not of itself have any significant impact on renewable energy growth in NSW. It’s not intended to; a sharp rise in renewable energy use would undermine the NSW Government’s revenue model, which includes the sale of its coal fuelled generating installations. The dREAP has however been released at the beginning of a market driven energy revolution that is likely to leave the Government's preferred model behind within the next decade.

The Government's preference for fossil fuels is not in the public interest. It ignores the increasingly clear lower electricity generation cost benefits of renewable energy for domestic and business consumers, and it ignores the health, infrastructure and environmental costs of fossil fuels. It ignores the real and rising costs of climate change that drain tax revenues, increase insurance costs and cost lives.

The need to rapidly reduce greenhouse gas emissions

The current 'business as usual' global carbon dioxide (CO2) emission trends mapped by the IPCC will see atmospheric carbon dioxide reach 450 ppm (parts per million) between 2035 and 2040[15] beyond which global warming of at least two degrees centigrade (° C) is expected. In its 2011 World Energy Outlook the conservative International Energy Agency (IEA), of which Australia is a member nation, advised that globally 4/5 of the energy generating infrastructure required to 'lock-in' 450 ppm is already installed and operational.[16] The IEA warns that current plans will see the remaining power generation infrastructure required to guarantee 450 pm completed by 2017. That is, there is little time left to adopt policies and accordingly deploy low or zero carbon infrastructure in order to stand a reasonable chance of avoiding warming of two or more degrees centigrade.

The IEA Outlook report comments; "*Delaying action is a false economy: for every $1 of investment in cleaner technology that is avoided in the power sector before 2020, an additional $4.30 would need to be spent after 2020 to compensate for the increased emissions*."

In its 2011 Golden Age of Gas report[17] the IEA warns that the current transition to gas trend will lead to an atmospheric CO2 concentration of 650 ppm and global warming of at least 3.5° C. Noting that once built electricity generating infrastructure will typically require an operating lifetime of 20 or more years in order to be economically viable, the window of opportunity to responsibly use gas as a transition fuel has passed. That is, gas can no longer be regarded as a panacea for climate change.

In that context then, the NSW Renewable Energy Action Plan (REAP) should map a path away from coal and gas as power sources and offer incentives for the deployment of renewable energy sources. The Australian Energy Market Operator (AEMO) 2012 National Electricity Forecasting Report advises that in NSW the low reserves point will not be reached until at least 2020. There remains then a reasonable window of opportunity in which to commence the wide spread deployment of renewable energy sources and phase out fossil fuel sources. With gas currently providing only 6% or so of the State's electricity generating capacity, NSW is in an excellent position to become Australia's leading renewable energy state.

Further Cost Benefit Considerations

Currently South Australia leads the country [18], indeed much of the world, in the deployment of renewable energy systems - wind in particular (see Table 1). In 2011 wind power averaged 26% of the electricity supply in South Australia, up from 1% just 5 years earlier. During high wind periods SA exports electricity to other states. The SA supply capacity from wind reached 31% in May of this year, prompting independent analysts Energy Quest to describe wind as the new baseload for South Australia.[19] In isolation wind is not able to act as a reliable baseload source, however prudent deployment across geographically dispersed locations in conjunction with storage equipped solar thermal is capable of baseload supply. The increasing use of wind generated electricity in SA has not caused the lights to ‘go out’. South Australia is turning the challenge of wind into an opportunity and consumers are reaping the benefits.

South Australia also leads in the deployment of rooftop solar PV, which contributed 3% of the state’s supply in 2011. Wind and solar contribute about a third of the electricity in SA.[18(b)]

Table 2 NEM Power Generation March quarter 2012, % Market Share

	Coal	Gas	Hydro	Wind	Oil	Solar PV	GWh Total
NSW	88.3%	5.9%	4.0%	0.9%	0.0%	0.9%	100%
Queensland	78.0%	20.1%	1.0%	0.0%	0.0%	0.9%	100%
SA	26.0%	39.5%	0.0%	31.0%	0.0%	3.5%	100%
Tasmania	0.0%	19.6%	74.3%	5.9%	0.0%	0.2%	100%
Victoria	93.4%	0.9%	2.7%	2.5%	0.0%	0.6%	100%
Total	**79.3%**	**11.2%**	**5.4%**	**3.1%**	**0.0%**	**0.9%**	**100%**

Sources: EnergyQuest, AEMO, PV Output

Table 1. Distribution of electricity dispatch (not capacity) in the first quarter of 2012.[18(b)] Of note, while hydroelectric generation in NSW can in principle provide at least 16% of the total generating capacity, the operating contribution is significantly lower.

As a consequence of the deployment of renewable energy, primarily wind, wholesale electricity prices fell by 50% in the March quarter of 2012. The SA government is calling for those reductions to be passed on to the consumer.[20]

Of note, while NSW has a significant hydroelectricity capacity, the figures in Table 1 show that it provided only 4% of the supply in the first quarter of this year. Presumably this reflects policy settings that accommodate the competing power, irrigation and environmental demands for water.

According to Energy Quest, lower demand for grid power and the growth of wind and solar pushed average wholesale electricity prices down between 30-60 per cent in all eastern states, except Tasmania.[21] Nonetheless retail electricity prices have increased in these states.

The ACCC and Productivity Commission attribute this disparity to poor regulatory practices and excessive investment in transmission infrastructure.[22] The contribution of the carbon price is significantly less than the fall in wholesale prices and has associated compensation provisions. In NSW part of the problem is that the Independent Pricing and Regulatory Tribunal (IPART) has used inaccurate forecasts for renewable energy certificate costs in setting the maximum (i.e. default) market price for electricity.[23]

The draft REAP has an emphasis on delivering renewable energy at least cost to the consumer and tax payer. To do so the NSW Government will need to address the excessive transmission costs and costs arising from poor regulation.

The NSW Government will also have to address its contradictory positions on energy resources. In particular it will have to change its stance on wind farms. Wind power is low cost and rapidly deployed, yet the Government has made clear its opposition to wind farms.

NSW Government policy and preferences

The draft REAP has been released in the context of contradictory positions adopted by the NSW Government with respect to energy that are not conducive to renewable energy investment in NSW.

The draft REAP refers to the draft NSW Wind Farm Guidelines that are, like those enacted in Victoria, regarded as among the strictest in the world - in a country with the second lowest population density in the world just behind that of Mongolia. The Victorian legislation has already had a negative impact on wind power investment in that state.[1,24]

In late 2011 the Premier Barry O'Farrell publically expressed a personal disdain for wind power, saying "*... I'm told no new applications have been lodged, we haven't approved any applications - and if I had my way, we wouldn't,*"[1] There have been no further wind farm proposals. The minister responsible for the draft NSW guidelines, Minister for Planning Brad Hazzard, has indicated that the majority of current proposals for wind farms would not meet the requirements set out in the draft guidelines.[2]

The NSW Government asserts that its draft wind power guidelines reflect an application of the Precautionary Principle taken to minimise or avoid harmful impacts from the deployment of wind turbines. In January Minister Hazzard made the following statement; "*I take the view that the jury is still out on the health impacts from wind farms ...* ," and "*When it comes to people's health, I'll take a precautionary approach every time*."[3] As discussed below, a precautionary approach is not applied to coal.

While the jury may perhaps be out in the mind of the Minister and others in the Government, and in the minds of the anti-wind lobby, there is no peer reviewed science to support the Minister's position. The NSW Department of Health has advised the government that concerns that wind turbines make people sick are *"not scientifically valid*".[3] The advice of the Department of Health is evidence based and reflects assessments in at least 18 authoritative review publications[25-43], including a 2010 review from the National Health and Medical Research Council.[31] The 2011 Federal Senate Inquiry into the social and economic impact of rural wind farms found no scientifically established links between wind farms and adverse health effects.[44] Given there are now some 200,000 turbines in use around the world[45] with a total generating capacity of some 254,000 MW[45(b)], it would be reasonable to expect that adverse health impacts would be readily established. Professor Simon Chapman recently provided some interesting insight into the ‘clustering’ and character of wind farm ‘ailments’.[45(a)] The position of the Minister is not evidence based. The disdain for wind farms expressed by the Premier is not reflected in surveys that show majority support for wind power in NSW, including in the immediate vicinity of wind farms.[56]

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NSW, with a population of 7 million and a land area more than twice that of Germany has about 280 MW of installed wind capacity (semi-scheduled and non-scheduled), or 1.65% of the States 17,000 megawatts (MW) of installed electricity generation capacity.[17] Gas provides some 6% of the electricity in NSW.

At the end of 2011 Germany, with a land area just under half of that of NSW and a population of 81 million had 29,075 MW of installed wind driven generator capacity, with 2007 MW installed in 2011 alone.[46(a)]. A further 1004 MW were added in the first half of 2012, with a total additional capacity of 2400 MW expected by the end of the year. As of mid-2012, there are 22,664 wind turbines with a combined capacity of 30,016 MW in operation in Germany.[46(b,c)] Some of its increased capacity will come from the replacement of older turbines with more efficient modern systems. Renewable energy currently provides 25% of Germany’s electricity and it expects to have 40% of its electricity supplied from renewable sources by 2020.[46(d)]

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The Premier has suggested bird populations would be decimated by wind farms. A 2011 review by the UK Centre for Sustainable Energy[43] puts bird strike by wind turbines in perspective: "*Wind turbines represent an insignificant fraction of the total number of bird deaths caused by man-made objects or activities (e.g. building structures, transmission lines, and keeping domestic cats)*." According to the CSE report, for every bird killed by a turbine there are on average 5,820 killed by striking buildings - typically glass windows. Aircraft and cars kill birds.

The Premier has dismissed wind power as incapable of supplying baseload power to NSW. This simplistic perspective ignores the valuable role wind can play in moving to a low carbon economy; a role recognised by the IEA. It ignores rapid developments in storage systems. A cost effective role benefiting electricity consumers has been demonstrated in South Australia and overseas. Baseload power considerations do not appear to be inhibiting the deployment of wind turbines beyond the borders of NSW - with the exception perhaps of Victoria. The traditional view of baseload is changing, as is the view of ‘gold-plated’ transmission infrastructure.

Contrary to Government and fossil fuel industry assertions, baseload capable renewable energy technology is deployable now.[47] Further sharp cost reductions are expected for renewable energy over the coming decade[9-12, 48,49]. Investing in this energy revolution now would deliver cost savings for all consumers and a business edge relative to those lagging behind. In 2010 NSW innovator Prof. David Mills suggested “*Costs are dropping so quickly that we may be able to very soon construct an inflexible plus flexible combination from solar and wind at much the same levelised cost as current coal plus natural gas combined cycle systems in the USA, and perhaps for Australia as well,*" says Mills. "*Wind is already there.*”[48] As a result of recent falls, the cost for solar PV generated electricity has now falling below that of fossil fuels.[9-12,49]

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The contrast between the draft NSW Wind Farm Guidelines and the requirements and provisions for the coal and gas industry evidently defines a government determined in its opposition to wind farms and strongly in favour of fossil fuel extraction. The draft Wind Farm Guidelines would impose an unnecessary and unjustified 35 decibel limit for wind farm noise, in contrast to requirements for other development types in NSW such as coal mines, coal trains and coal seam gas operations. As an example, the daytime noise requirement for the Metropolitan Colliery in Helensburgh is 50 dB(A) and at night it’s 45 dB(A). The sound of a coal train passing through the town at night is penetrating. The noise and inconvenience of coal trucks entering and leaving Helensburgh is likewise a community burden.

The draft Wind Farm Guidelines impose a set-back distance of 2 km - restriction that does not apply to coal mines or coal seam gas operations. A noteworthy example highlighting discrimination in favour of fossil fuels is that of the expansion of the Ashton open cut coal mine at Camberwell which, with strong local and regional opposition to the expansion proposal, was initially rejected by the NSW Planning and Assessment Commission (PAC) in late December 2011. Following a puzzling back-flip earlier this year by the NSW Office of Water, though with continuing internal division on the impacts of the project, the PAC reconsidered its position and approved the project earlier this month.[50] In doing so the PAC set aside the continued concerns and opposition from the NSW Department of Health. The Department of Planning and Infrastructure (DoPI) has consistently supported the project proposal and acted on behalf of the proponent.

The project includes property acquisitions, as have other mine approvals in the Hunter Valley. Camberwell was established in 1820 and is the oldest village in the Hunter. With the mine expansion bringing the mine to her doorstep, resident Wendy Bowman is left with little choice other than to sell her 150 hectare property to Ashton. The mine will destroy the property’s lush lucerne paddocks on the alluvial flats beside Glennies Creek. Wendy Bowan’s move will be the second relocation as a result of coal mining in the Hunter. Seven years ago her family farm Granbalang was resumed for the nearby Rix's Creek coal mine and its heritage homestead was demolished. The same fate awaits her current home and garden. The exiting Ashton coal mine is also within one kilometre of Camberwell - on the other side of the dying village.

Each phase of coal's lifecycle: mining, disposal of contaminated water and tailings, transportation, washing, combustion, and disposing of post-combustion wastes, produces pollutants that affect human health and impose costs on the tax-payer.[51] Open cut and longwall coal mines inflict far greater environmental and amenity impacts than would a wind farm. Environmental impacts include the loss of productive agricultural land, damage to aquifers and water supply catchments and the release of dust and combustion pollutants. The so called ‘external’ costs[51(c,d)] associated with a coal mine are not taken into consideration when the ‘bigger picture benefit’ of a coal mine proposal is assessed - that is, when the royalty dividend is calculated. These costs are substantial.[51(c,d)]

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Assessments of coal and gas projects do not consider the costs arising from climate change, felt for instance in the sharply rising costs for insurance against flood, drought and bushfire. Climate change effects human health and well-being.

The environmental costs of coal and gas were not taken into consideration in IPART’s 2012 determination of a ‘fair and reasonable’ feed-in tariff for roof-top solar electricity panels.

The feedstock for wind and solar energy yields no royalties. While the NSW Government is willing to recycle fossil royalties in subsidies back to the industry, such as subsidy support for the Cobbora coal mine[52], it will not provide incentives for the renewable energy industry; there are no financial incentives associated with the draft REAP.

NSW government opposition to the RET and a price on carbon

The dREAP has been released by a State Government opposed to the RET and opposed to a price on carbon. In April 2012 the Minister for Resources and Energy Chris Hartcher advised “*The NSW Government is calling for the immediate review of those green policies and schemes that deliver subsidies to industry at the broader expense of the community, and the closure of the Federal Renewable Energy Target*.”[4] As mentioned, the Premier has written to the Prime Minister in opposition to the LRET.

In its submission to the recent RET review, the NSW Independent Pricing and Regulatory Tribunal (IPART) has recommended scraping the RET, describing it as expensive and incorrectly suggesting that its “*not complementary*” to the carbon price.[53] This recommendation has called into question IPART’s credibility as an independent body. [53(b)]

IPART’s opposition to the RET ignores the environmental benefits of renewable energy and ignores its own contribution to costs arising from the RET.[53(b)] In effect, IPART has provided the now privatised electricity retailers in NSW with a no-risk windfall profit, at NSW electricity customers’ expense, by passing through over-estimated renewable energy certificate prices – some 21 to 26 per cent above the actual market price for the certificates.

Compounding the problem for electricity consumers in NSW, IPART has serially approved large electricity price increases in NSW since 2007. In part that are imposed under the current wholesale electricity pricing framework overseen by the Australian Energy Regulator (AER), with IPART setting retail prices. The current pricing regime was intended to ensure that future privatised distribution corporations would have a guaranteed return based on the value of their assets, thus providing an incentive to invest in infrastructure; something they might not otherwise do. As a result however there has been over-investment, or 'gold plating', to bolster returns. These returns also deliver a dividend to the NSW government, which still owns the distribution network.

The NSW Government, the fossil fuel industry and its other supporters argue that the RET inflates electricity prices. The argument ignores the clear evidence that renewable energy puts downward pressure on electricity prices and compensates for RET costs.[20(c),53(e-g)] The argument ignores the additional benefits of renewable energy, which removes the external costs associated with the fossil fuel industry and reduces greenhouse gas emissions. Energy analysts AECOM contend that the RET delivers energy price security by quarantining domestic prices from international shocks such as Hurricane Katrina, super-storm Sandy, oil price surges, or extreme weather conditions in Australia which could restrict gas output.[53(a)]

The Clean Energy Council estimates that the cost of all renewable energy schemes, including RET and state-based FiT schemes, constitutes 4-7% of average retail electricity bills; far less than costs arising from transmission infrastructure.

The NSW Government is also opposed to the carbon price, which IPART sees as rendering the RET redundant, with Minister Hartcher stating in April that "*It's crucial that households and small businesses are aware of how much Labor's carbon tax and green schemes will contribute to power prices rises and we will continue to campaign against Labor's devastating tax*."[4]

The Commonwealth Treasury had estimated that the consumer price index (CPI) would rise by 0.70 percent as a result of the carbon tax, with the consequential weekly rise of $9.90 being compensated by an average $10.10 being returned to consumers from the tax. The September quarter figures however show an increase of only 0.44 percent to the CPI as a result of the carbon price.[54]

Contrary to the assertions of the NSW Government, the measures put in place to encourage investment in renewable energy have a modest impact on electricity prices, offset by consequential downward pressure on prices, environmental benefits and health and social welfare benefits.

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Recommendations

Recommendation 1: The NSW Government put in place polices and incentives that will provide NSW with a 20% renewable energy capacity in addition to the current capacity by 2020. South Australia has demonstrated the benefits of increasing levels of renewable energy capacity. Cheaper electricity benefits domestic, business and industrial users and will increase national and international competitiveness.

Recommendation 2: The NSW Government revise its wind farm guidelines to remove the significant disincentives to investment.

Recommendation 3: The NSW Government capitalise on the current window of opportunity to take an industrial and business lead in concentrated solar energy with storage.

Recommendation 4: The NSW Government phase out subsidies for the fossil fuel industry and instead provide incentives for renewable energy sources, energy efficiency measures and electric vehicles.

Recommendation 5: IPART set a price for small scale renewable electricity sources that recognises their environmental benefit, including greenhouse gas reduction and other environmental impact avoidance.

Recommendation 6: The NSW Government work with the other states and the Commonwealth to establish national regulation of retail electricity pricing.

Recommendation 7: The NSW Government work with the other states and the Commonwealth to establish national feed-in tariff for small scale renewable energy sources.

Recommendation 8: NSW Government work with the other states and the Commonwealth to establish a national approach to smart grids.

Recommendation 9: The Renewable Energy Action Plan show both the available capacity for hydroelectricity and the average dispatch over the past year from hydroelectricity. The water used for hydro-electric generation has competing uses that limit its availability for power generation.

Recommendation 10: The Renewable Energy Action Plan refer to the most recent BNEF paper to make clear the fall in the price of solar PV and the consequential implications for ‘socket’ parity.

References

[1] http://www.smh.com.au/environment/energy-smart/premier-denies-wind-of-change-20110816-1iwgc.html

[2] http://www.climatespectator.com.au/commentary/gone-wind-planning-laws-blow-away-investment

[3] http://www.smh.com.au/environment/energy-smart/science-on-wind-turbine-illness-dubious-say-experts-20120123-1qe98.html

[4] http://www.trade.nsw.gov.au/__data/assets/pdf_file/0019/430174/120411_Minister-Hartcher-med-rel-Carbon-tax-and-green-schemes.pdf

[5] http://reneweconomy.com.au/2012/nsw-premier-ofarrell-does-backflip-on-20-renewables-target-27646

[6] http://www.abc.net.au/news/2012-08-17/csg-will-be-accepted2c-just-like-uranium3a-hartcher/4206622

[7] (a) http://www.aemo.com.au/en/Electricity/Planning/Related-Information/Generation-Information (b) http://www.aemo.com.au/Electricity/Resources/Reports-and-Documents/National-Electricity-Forecasting/Information-Papers-2012

[8] http://www.smh.com.au/environment/energy-smart/renewable-energy-to-rise-without-cost-to-public-20120907-25jnu.html

[9] (a) www.bnef.com/WhitePapers/download/82 **(b)** http://reneweconomy.com.au/2012/solar-pv-its-cheaper-than-you-think-58689 **(c)** http://www.climatespectator.com.au/commentary/embrace-solar-snowball

[10] http://www.climatespectator.com.au/commentary/wind-and-solar-price-crunch

[11] http://reneweconomy.com.au/2012/solar-insights-pv-costs-set-for-another-30-fall-in-2012-2012

[12] http://reneweconomy.com.au/2012/solar-pv-will-do-to-grids-what-mobiles-did-to-telephony-19153

[13] (a) http://www.eia.gov/coal/production/quarterly/ (b) http://spectrum.ieee.org/energywise/energy/fossil-fuels/dramatic-trends-in-us-coal-consumption-and-exports (c) http://www.marketwatch.com/story/us-2012-coal-use-to-fall-to-25-year-low-eia-2012-05-08 (d) http://www.eia.gov/coal/production/quarterly/pdf/t1p01p1.pdf (e) http://www.eia.gov/FTPROOT/coal/coal_production_review.pdf (f) http://www.theglobalmail.org/feature/coal-its-over/448/ (g) http://www1.eere.energy.gov/wind/pdfs/2011_wind_technologies_market_report.pdf (h) http://www.businessweek.com/articles/2012-04-26/coals-future-is-rocky-at-best (i) http://afr.com/p/national/cost_of_coal_undermining_its_future_8BfFLpfAISweRcAUq62XRK

[14] http://www.abc.net.au/unleashed/4337870.html (b) http://www.abc.net.au/7.30/content/2012/s3430889.htm (c) http://news.nationalgeographic.com.au/news/energy/2012/05/120522-carbon-capture-and-storage-economic-hurdles/ (d)

[15] (a) http://www.ipcc-data.org/ddc_co2.html; (b) http://www.skepticalscience.com/iea-co2-emissions-update-2010.html

[16] (a) http://www.iea.org/weo/ (b) http://www.iea.org/weo/docs/weo2011/factsheets.pdf (c) http://www.guardian.co.uk/environment/2011/nov/09/fossil-fuel-infrastructure-climate-change

[17] (a) www.iea.org/weo/docs/weo2011/WEO2011_GoldenAgeofGasReport.pdf; (b) http://www.guardian.co.uk/environment/2011/jun/06/natural-gas-climate-change-no-panacea

[18] http://www.climatespectator.com.au/commentary/are-lights-still-south-australia (b) http://reneweconomy.com.au/2012/mixed-greens-wind-and-solar-provide-13-of-power-in-sa-69923

[19] (a) http://www.energyquest.com.au/insightsandanalysis.php?id=136; (b) http://www.energyquest.com.au/insightsandanalysis.php?id=130; (c) http://www.climatespectator.com.au/news/solar-wind-grow-share-march-qtr-wind-new-baseload-sa-report; (d) http://www.climatespectator.com.au/commentary/south-australia-busts-wind-myths

[20] http://www.abc.net.au/news/2012-10-02/power-costs-saving-promised-for-some-sa-customers/4290892; (b) http://www.climatespectator.com.au/commentary/wind-power-nice-theory-better-practice; **(c)** http://www.climatespectator.com.au/commentary/are-renewables-driving-power-prices-lower **(d)** http://reneweconomy.com.au/2012/how-wind-power-helps-lower-electricity-prices-22968

[21] (a) http://www.energyquest.com.au/uploads/docs/releasewinds_increasing_role_in_power_generation_as_gas_usage_drops_13_in_march_quarterfinal.pdf; (b) http://reneweconomy.com.au/2012/mixed-greens-wind-and-solar-provide-13-of-power-in-sa-69923

[22] (a) http://www.accc.gov.au/content/index.phtml/itemId/1086424 (b) http://www.pc.gov.au/projects/inquiry/electricity/draft (c) http://www.abc.net.au/worldtoday/content/2012/s3613307.htm (d) http://www.climatespectator.com.au/commentary/productivity-commission-releases-bomb

[23] (a) http://reneweconomy.com.au/2012/has-ipart-lost-its-energy-independence-69079 (b) http://www.climatespectator.com.au/commentary/o-farrell-s-renewable-energy-wonderland

[24] http://www.abc.net.au/radionational/programs/breakfast/regulations-killing-victorian-wind-farms/4155732

[25] 2012: Massachusetts Department of Environmental Protection. Independent Expert Science Panel Releases Report on Potential Health Effects of Wind Turbines http://www.mass.gov/dep/public/press/0112wind.htm

[26] 2012: Oregon Wind Energy Health Impact Assessment.

http://public.health.oregon.gov/HealthyEnvironments/TrackingAssessment/HealthImpactAssessment/Documents/Oregon Wind Energy HIAPublic comment.pdf

[27] Fiumicelli D. Windfarm noise dose-response: a literature review. Acoustics Bulletin 2011; Nov/Dec:26-34

[28] 2011: Bolin K et al. Infrasound and low frequency noise from wind turbines: exposure and health effects. Environmental Res Let 2011; http://iopscience.iop.org/1748-9326/6/3/035103/

[29] 2010: Knopper LD, Ollsen CA. Health effects and wind turbines: a review of the literature. Environmental Health 2010; 10:78 http://www.ehjournal.net/content/10/1/78

[30] 2010: UK Health Protection Agency Report on the health effects of Infrasound http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1265028759369

[31] 2010: NHMRC Rapid Review of the evidence http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/new0048_evidence_review_wind_turbines_and_health.pdf

[32] 2010: Chief Medical Officer of Health in Ontario http://www.health.gov.on.ca/en/public/publications/ministry_reports/wind_turbine/wind_turbine.pdf

[33] 2010: UK Health Protection Agency. Environmental noise and health in the UK. A report by the Ad Hoc Expert Group on Noise and Health. http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1279888026747

[34] 2009: Minnesota Department of Health. Environmental Health Division. Public Health Impacts of Wind Turbines. http://www.health.state.mn.us/divs/eh/hazardous/topics/windturbines.pdf

[35] 2009: Canadian Wind Energy Association. Addressing Concerns with Wind Turbines and Human Health. CanWEA, Ottawa.http://www.canwea.ca/pdf/CanWEA - Addressing concerns with wind turbines and human health.pdf

[36] 2009: Colby et al. Wind Turbine Sound and Health Effects: An Expert Panel Review.

http://199.88.77.35/EFiles/docs/CD/PlanCom/10_0426_IT_100416160206.pdf

[37] 2008: Chatham-Kent Public Health Unit

.http://www.harvestingwindsupport.com/blog/wpcontent/uploads/2011/03/ChathamKentHealh-and-Wind-.pdf

[38] 2007: National Research Council (USA): Impact of wind energy development on humans (Chapter 4: pp97-120) of: Environmental Impacts of Wind-Energy Projects.

http://www.vawind.org/assets/nrc/nrc_wind_report_050307.pdf

[39] 2005: Jakobsen J. Infrasound emission from wind turbines. J. Low

Frequency Noise, Vibration and Active Control 2005; 24(3):145-155

[40] 2004: Leventhall G. Low frequency noise and annoyance. Noise & Health

2004;.6(23):59-72 http://tinyurl.com/4yc3oht

[41] 2004: Leventhall G. Low frequency noise and annoyance. Noise & Health

2004;.6(23):59-72 http://tinyurl.com/4yc3oht

[42] 2003: Review for the Swedish EPA

http://www.naturvardsverket.se/Documents/publikationer/620-5308-6.pdf

[43] http://www.cse.org.uk/downloads/file/common_concerns_about_wind_power.pdf

[44] The Social and Economic Impact of Rural Wind Farms, The Senate Community Affairs References Committee, Commonwealth of Australia June 2011. ISBN 978-1-74229-462-9. Printed by the Senate Printing Unit, Parliament House, Canberra.

[45] (a) http://www.abc.net.au/radionational/programs/scienceshow/curious-distribution-for-wind-turbine-sickness/4323486; (b) http://www.wwindea.org/home/index.php

[46] http://www.silobreaker.com/german-wind-energy-stands-at-29075-mw-5_2265531839890325588; [b] http://www.sunwindenergy.com/news/german-wind-power-market-growing; (c) http://www.businessweek.com/ap/2012-08-01/german-wind-power-installation-up-26-percent; (d) http://www.climatespectator.com.au/news/germany-raises-renewables-target-40-eyes-cap-support (e) http://www.sunwindenergy.com/news/german-wind-power-market-growing

[47] (a) http://www.beyondzeroemissions.org/ (b) http://www.zerocarbonbritain.com/ (c) http://www.guardian.co.uk/environment/blog/2010/sep/28/salmond-green-electricity-scotland (d) http://www.guardian.co.uk/environment/2010/sep/29/wind-fossil-fuel-denmark-2050 (e) http://www.wwf.org.uk/news_feed.cfm?4584/The-Energy-Report---100-renewable-energy-by-2050 (f) http://www.dailymail.co.uk/sciencetech/article-1393879/Gemasolar-Power-Plant-The-worlds-solar-power-station-generates-electricity-NIGHT.html (g) http://www.reuters.com/article/2011/05/09/us-energy-renewables-idUSTRE7481L220110509 (h) http://www.upi.com/Business_News/Energy-Resources/2011/06/20/Work-starts-on-worlds-largest-solar-plant/UPI-79461308570916/ (i) http://www.guardian.co.uk/environment/2010/jul/07/germany-renewable-energy-electricity (j) http://www.renewableenergyworld.com/rea/news/article/2011/03/wind-becomes-spains-biggest-energy-source (k) http://www.renewableenergyworld.com/rea/news/article/2011/03/wind-becomes-spains-biggest-energy-source (l) Jacobson, M. Z. & Delucchi, M. A. Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials. Energy Policy. doi:10.1016/j.enpol.2010.11.040 (2010). (m) Delucchi, M. A. & Jacobson, M. Z. Providing all global energy with wind, water, and solar power, Part II: Reliability, system and transmission costs, and policies. Energy Policy. doi:10.1016/j.enpol.2010.11.045 (2010). (n) http://www.energy.ca.gov/siting/solar/index.html (o) http://af.reuters.com/article/energyOilNews/idAFTOE65N03E20100624; (p) Ben Elliston, Mark Diesendorf and Iain MacGill; *Simulations of Scenarios with 100% Renewable Electricity in the Australian National Electricity Market*; Solar2011, the 49th AuSES Annual Conference, 30 November–2 December 2011. (q) http://www.cleanenergycouncil.org.au/dms/cec/reports/2012/CSP_AUST_Final_May2012

[48] http://www.climatespectator.com.au/commentary/new-pillars-power;

[49] (a) http://www.abc.net.au/news/2011-09-07/solar-industry-celebrates-grid-parity/2875592/?site=sydney (a) http://www.garnautreview.org.au/update-2011/commissioned-work/renewable-energy-technology-cost-review.pdf (c) Interactions of Policies for Renewable Energy and Climate. IEA 2011. http://www.iea.org/papers/2011/interactions_policies.pdf (d) http://www.climatespectator.com.au/commentary/renewables-price-right (e) http://www.climatespectator.com.au/commentary/why-wind-cutting-energy-costs (f) http://www.climatespectator.com.au/commentary/busting-renewables-price-myth (g) http://www.climatespectator.com.au/commentary/wind-and-solar-price-crunch; (h) http://www.climatespectator.com.au/commentary/embrace-solar-snowball; (i) http://reneweconomy.com.au/2012/solar-insights-pv-costs-set-for-another-30-fall-in-2012-2012 (j) http://www.newenergyfinance.com/free-publications/white-papers/ ; (k) http://theconversation.edu.au/newsflash-solar-power-costs-are-falling-below-fossil-fuels-7215; (l) http://reneweconomy.com.au/2012/solar-pv-its-cheaper-than-you-think-58689 (m) http://www.climatespectator.com.au/commentary/embrace-solar-snowball (n) http://reneweconomy.com.au/2012/solar-insights-pv-costs-set-for-another-30-fall-in-2012-2012

[50] http://www.theherald.com.au/story/382462/ashton-coal-mine-at-camberwell-approved/ (b) http://www.theherald.com.au/story/399037/opinion-ashton-coalmines-benefit-insignificant/; (c) http://www.miningaustralia.com.au/news/camberwell-coal-mine-plan-renewed

[51] (a) http://dea.org.au/news/article/the_mining_and_burning_of_coal_effects_on_health_and_the_environment (b) http://www.abc.net.au/news/2012-10-29/new-report-highlights-health-fears-for-hunter-valley/4338446 (c) Epstein, P. Full cost accounting for the life cycle of coal, Annals of New York Academy of Sciences, 1219: 73-98.(d) Muller, N et al. Environmental Accounting for Pollution in the United States Economy, American Economic Review, August 2011, 101, pp.1649–1675.

[52] (a) http://www.climatespectator.com.au/commentary/nsws-great-big-coal-subsidy-scandal ; (b) http://www.parliament.nsw.gov.au/prod/parlment/hansart.nsf/V3Key/LC20120821043

[53] (a) http://www.ipart.nsw.gov.au/files/2ee94a2c-08f7-4862-be7e-a0cc00f05e3d/IPART_Submission_-_Climate_Change_Authority_-_Renewable_Energy_Target_Review_-_September_2012.pdf ; (b) http://reneweconomy.com.au/2012/has-ipart-lost-its-energy-independence-69079 (c) IPART wants energy target dumped - Sydney Morning Herald; (d) http://theconversation.edu.au/the-real-cause-of-electricity-price-rises-in-nsw-8955 (e) http://www.climatespectator.com.au/commentary/ret-debate-rolls (f) http://www.cleanenergycouncil.org.au/dms/cec/reports/2012/Benefit-of-the-Renewable-Energy-Target-to-Australias-Energy-Markets-and-Economy-pdf (g) http://www.cleanenergycouncil.org.au/dms/cec/reports/2011/Impact-of-renewable-energy-and-carbon-pricing-policies-on-retail-electricity-prices

[54] http://www.smh.com.au/national/impact-of-carbon-tax-lower-than-predicted-20121024-285us.html

[55] (a) http://reneweconomy.com.au/2012/five-things-we-learned-from-clean-energy-week-69430 (b) http://www.smh.com.au/opinion/political-news/gas-exports-come-at-a-cost-20121016-27p42.html

[56] (a) Community Attitudes to Wind Farms in NSW, report to Department of Environment, Climate Change and Water NSW by AMR Interactive December 2010. (b) http://www.smh.com.au/environment/energy-smart/strong-support-for-wind-farms-obscured-says-csiro-report-20120117-1q4pj.html (c)http://www.csiro.au/Organisation-Structure/Flagships/Energy-Transformed-Flagship/~/media/CSIROau/Flagships/Energy%20Transformed%20Flagship/Exploring%20community%20acceptance%20of%20rural%20wind%20farms%20in%20Australia%20a%20snapshot_CSIRO2012_Report.pdf **(d)** Attitudes to wind energy in Victoria, NSW and South Australia. Pacific Hydro November 2011. http://www.pacifichydro.com.au/english/information-centre/wind-

market/community-support/?language=en **(e)** Wind Energy Community Research in Victoria, New South Wales and South Australia; Clean Energy Council, April 2012. http://www.cleanenergycouncil.org.au/dms/cec/reports/2012/120507-Qdos-Wind-Polling-report

[57] http://afr.com/p/business/companies/nsw_govt_hints_at_coal_seam_gas_kYbDhxNSX4emlOYEPdBi6N (b) http://theland.farmonline.com.au/news/state/agribusiness-and-general/general/nsw-looks-to-mine-csg-for-domestic-use/2628193.aspx

Transcript for 'Taking Our Temperature', ABC Catalyst, November 15 2012

***Video Link*:** http://www.abc.net.au/catalyst/stories/3633447.htm

Narration

Dr Jonica Newby

Have you noticed anything odd round your place lately? A fish you've never caught before. Unusual events. Weird weather. Well, I've certainly noticed something odd round my home.

I bought this place 12 years ago. And, in that whole time, it never flooded. Nor in the 20 years the old guy had it before me. In the last two years, it's flooded ten times.

I've pretty much stopped mopping. And, like many of us, as I survey the damage, I wonder if this is Climate Change, a rogue La Nina or just a really rainy year. Has the weather changed in the last 100 years or not? So, I'm heading on an investigation that's all about the simple facts. Real tidal gauges, actual temperature records. And this will be a proper weather report, going round Australia to the places you and I live and play. It's time to take the temperature of Australia. And, when it comes to weather, there's one organisation perfectly placed to guide me. They formed 100 years ago. They are the Bureau of Meteorology.

Dr Jonica Newby
Hello, Karl.

Dr Karl Braganza
How's it going, Jonica?

Dr Jonica Newby
Good. And... So you're going to run us through a national, 100-year Australia health check/weather report.

Dr Karl Braganza
That's right. Today we're going to do a national round-up of Australia's temperature, hydration and its circulation.

Dr Jonica Newby
Fantastic. So I reckon we start straightaway with temperature, which means I'm heading... here.

NARRATION
I don't want to start with the heat, but with the cold. Is it as cold as it used to be? And where better to view the cold than from our nation's frosty tips? Our enchanted, legendary snowy mountains...

where I love to ski.

Dr Jonica Newby
You may think me elitist, but I prefer to think it's the genetic imperative of my Norwegian ancestry.

NARRATION
And those Nordic genes of mine have a keen interest in what's happened to the snow.

Dr Jonica Newby
Well, this is 1964, the biggest dump on record. You look at photos like this, and you think things must have changed. But have they really? Is it anecdotal or real? To find out, you have to go to the records.

NARRATION
We're off to Spencer's Creek, where the Snowy Hydro scheme has been taking snow-depth measures every week since 1954. Dr Ken Green has been monitoring the snow for decades.

Dr Kenneth Green
We've got 65 inches, which...

Dr Jonica Newby
Inches?!

Dr Kenneth Green
Yes, inches. It's been done since 1954. So they're not going to change their methods now.

Dr Jonica Newby
(Laughs)

Dr Kenneth Green
Which is about... 162cm.

NARRATION
Snow cover swings wildly from year to year. So the best way to see the signal in the record is to compress it into five-year average trends.

Dr Jonica Newby
So, how are we going to do the trend line?

Dr Kenneth Green
We'll put this in as the trend line.

NARRATION
Hmm. In 60 years, we've lost a third of our total snow cover. But there is some rough comfort for my skiing aspirations. And that is that the beginning of the season hasn't really changed.

Dr Jonica Newby
So, basically, since 1954, snow depth in July is much the same. When you reach September, it starts to drop off. So that by October it's noticeably less. Essentially, spring is coming earlier.

NARRATION
It's even clearer when you look at the records for the thaw, now two weeks earlier than in the '60s. And the snowline appears to have lately moved up from 1,500m to 1,600m.

Dr Kenneth Green
This actually used to be a ski run, coming down here across the road. And now you wouldn't even dream of it.

NARRATION
So what HAS happened to Australia's cold?

Dr Jonica Newby
Right. Our first national round-up. So we're looking at minimum temperatures. And, Karl, basically, this is how cold it gets at night.

Dr Karl Braganza
That's correct, Jonica. If we start at the Snowy here, we've warmed by about 1.1 degrees since a century ago. And that's similar to Perth, Sydney. If we're looking over here at Cairns, it's almost 2 degrees since 1910.

Dr Jonica Newby
Two degrees, so hot nights.

Dr Karl Braganza
Well, hotter nights than they used to have, yeah - on average.

NARRATION
And how do we know this to be true? Well, because, frankly, the data collection behind it is mind-boggling. This is the Victorian regional headquarters of the Bureau of Meteorology.

Dr Jonica Newby
So how many things are kind of feeding into all of this?

Kevin Parkyn
Um, too much, really for the brain to comprehend, to be honest. And that's why we have a lot of alerts that help us.

NARRATION
There are nearly 800 weather stations across Australia, with over 500 now fully automated. Of these, 112 sites have information that historically goes back far enough and is accurate enough to

count as blue-chip and be used as part of the 100-year record.

Dr Jonica Newby
OK, so, to be in the top 100, you have to have a few things going for you. First of all - quality instruments. So this is a fully automated platinum temperature probe. Second, you have to have reliable records. So these platinum records go back to 2001. And then this old-fashioned but still accurate mercury goes back to 1910.

NARRATION
Third, the station has to be well away from urban heat islands, so not in a big city. All this data is then fed by cables to central stations at the national bureau headquarters in Melbourne, where it ends up here.

Dr Jonica Newby
I'm on the secret level of the bureau now. This is the lair of the weather supercomputers. They have their own full-time staff of 22 IT slaves on 24-hour call making sure nothing upsets them.

NARRATION
A gazillion cable feeds are swallowed here, digested and then spat over there.

Dr Jonica Newby
This temperature controlled block of pampered bits and bytes contains all the records. This, essentially, is the history of Australia's weather.

NARRATION
And this is how the bureau knows how much minimum temperatures have gone up in 100 years.

Dr Jonica Newby
So that's night-time minimums, but I bet what most of you are more interested in is what's happened to daytime maximums. And, for that... I'm heading here.

NARRATION
This is another one of my favourite spots in Australia - sassy, sexy, St Kilda, Melbourne.

Dr Jonica Newby
I lived here in my 20s, and, coming from Sydney and Perth, can I say Melbourne had a bit of a reputation for its weather?

NARRATION
So, when I moved here, I bought a coat, a scarf, gloves, and these, but what no-one told me was how darn hot it was going to get. And I'm not the only one shedding her coat early. Butterflies are really temperature-sensitive. Melbourne's common brown butterfly now emerges from its chrysalis nearly two weeks earlier than in 1940. So, how much hotter has Melbourne got?

Dr Jonica Newby

OK, Doctor, our national round-up of maximum temperatures. So what do we have?

Dr Karl Braganza
You can see here - Sydney through to Melbourne, Canberra, Hobart, they've warmed up by about 0.7 of a degree. And in some capitals a lot less. Adelaide - 0.3. But if you go over to the west - Perth - and into the centre - Alice Springs - you've got 1.1 to almost 2 degrees of warming.

Dr Jonica Newby
Wow.

NARRATION
In 100 years, the centre has heated up more than the coast.

Dr Jonica Newby
So, the further inland you are, in Australia, the more the maximum temperatures will have gone up?

Dr Karl Braganza
As a general trend, yeah.

NARRATION
Overall, averaging maximums and minimums, our nation's core temperature has gone up 0.9 of a degree. But, in 2009, Victoria's temperature spiked in a lethal fever.

Dr David Jones
In Melbourne we saw the previous February record broken by more than 3 degrees.

NARRATION
Melbourne hit 46.5 degrees. Hopetoun hit 48.8.

Dr David Jones
We broke the Victorian record by 1.6 degrees. You know, these are records going back over 50 years. You know, you're not breaking 'em by... by, you know, a few tenths of a degree - you're breaking 'em by whole degrees or more.

NARRATION
And you know what happened next. Of course, it became known as 'Black Saturday'. 173 people died in those fires, but they weren't the only casualties of this extreme heat event.

NARRATION
When health researchers went back over the mortality records, it turned out an extra 370 people died during that week than you'd expect.

Dr Jonica Newby
Essentially, it means that they were tipped over the edge by heat stress. There's a rather confronting in-house term that's used for this. They call it 'premature harvesting'.

NARRATION
And it isn't just humans feeling the heat. One day, on a country golf course way down south in WA, it started raining black cockatoos. It certainly surprised the locals, let alone the birds. The year was 2010, and the temperature hit 48 degrees. An entire flock of endangered Carnaby's cockatoos literally cooked where they roosted. And can you see what these are? Budgerigars. Budgerigars that fell from the sky during another WA heatwave in 2009.

Dr Jonica Newby
Alright, so this next diagnostic is... a measure of extremes.

Dr Karl Braganza
It is. And what we've seen is more and more stations are breaking extreme heat in the last 100 years, and less are breaking extreme cold.

NARRATION
In fact, in the last ten years, the number of stations breaking extreme heat records has doubled those breaking extreme cold.

Dr Karl Braganza
So, frosty nights are becoming less common, but extreme heat days are becoming more common.

NARRATION
Now, some of my friends like to joke that if things go really pear-shaped we can always move to Tassie. Well, one company already has. It's a company that makes something dear to many of our hearts - alcohol.

Dr Jonica Newby
I love the smell of baby wine growing in the morning.

NARRATION
Two years ago, a famously Victorian company bought up big here in Tasmania. And they did so specifically to future-proof themselves against temperature. They are the family dynasty Brown Brothers, though I seem to have found myself a Brown sister.

Dr Jonica Newby
So, had you actually noticed some damage to your bottom line, basically, due to temperatures?

Katherine Brown
Yeah. Um, we... Well, we put up with ten years of drought.

Dr Jonica Newby
Yeah.

Katherine Brown

Um, and also, um, one of our vineyards in Victoria where we grow our top-quality sparkling wines... We got the warmer weather earlier, and the bud bursts had already come through, so the frost came in and actually killed all the shoots. That wiped out a whole vintage.

NARRATION
The wine industry's detailed records show grapes in Australia's south are ripening, on average, 20 days earlier than in 1985.

Katherine Brown
Talking to our scientists, winemakers and viticulturists, um, they really pretty much turned to the board and said, 'We have to find this cooler-climate property because within decades we could see a 2-degrees temperature rise in our current vineyards in Victoria.' So, they pretty much told us that if we continued to want to do what we do best, make quality wine, we had to come south.

NARRATION
And now I'd like to demonstrate a little game of chance.

Dr Jonica Newby
So the chance of one month being above-average temperature, is one in two. The chance of the next month also being above-average temperature, is one in four. The chance of the next month also being above-average temperature, is one in eight.

NARRATION
So what do you think are the chances of having 330 months in a row of above-average temperatures? Because, since February 1985, we have had... 330 months in a row of above-average temperatures.

Dr Mark Howden
It's really extraordinary. If it was just by random chance alone, then there's only a 1 in 100,000 chance that that would have happened in the absence of human influence.

Dr Jonica Newby
So, this bottle of red represents the chance that that run of temperature increase was caused by natural variability, sunspots or volcanoes.

Dr Mark Howden
That's right.

Dr Jonica Newby
Right!

Dr Jonica Newby
I think we should drink it.

Dr Jonica Newby

Cheers.

NARRATION
So that's temperature. Next up, I want to check on Australia's state of circulation. I mean that stuff we're girt by - the sea. I'm still in Tassie because something odd has been happening in these waters - strange sightings, mysterious beasties where never before seen.

Dr Jonica Newby
I'm talking fish. And where there's fish, there's a fishing story.

Mark Nikolai
It was about two years ago, and I can remember it vividly. I saw a small group of fish come towards us. I said to my son, 'Wheel in your rod as fast as you possibly can.' When suddenly - bang. It just took off. The reel itself was actually screaming. My son didn't know what to do. He said, 'Dad, Dad, what do I do, what do I do?' I said, 'Nothing, son. Just hang on to the reel and wait for the fish to slow down.' So that's what we did. It took us about 40 minutes, I suppose.

Dr Jonica Newby
40 minutes?!

Mark Nikolai
40 minutes because the fish weighed more than the line capacity.

NARRATION
Brand spanking new to Tasmania, it was a yellow-tailed kingfish.

Dr Jonica Newby
A real yellow-letter day.

Mark Nikolai
That's it.

NARRATION
It's exciting times for Tasmanian fishermen. With so many new fish arriving, they've teamed up with scientists to plot them. They've seen leather jacks, green turtles, dusky morwong...

Mark Nikolai
It's actually really good news for Tasmanian fishermen, 'cause all the New South Wales fish are moving south into our waters.

NARRATION
All in all, scientists have confirmed 45 new species have, like Brown Brothers, shipped on down to Tassie.

Dr Jonica Newby

Well, obviously, if fish from the big island are moving down, the water here must have got warmer.

NARRATION
How much warmer?

Dr Jonica Newby
It's not too bad. Ooh, yes it is!

Dr Jonica Newby
Alright, Dr Karl. National round-up time again. 100-year health check. Circulation.

Dr Karl Braganza
Sure. What we're going to look at now, Jonica, is the sea-surface temperatures around Australia. And what we've seen is about a degree of warming over the last century. But you can see over the East Coast we have more warming than we do over the West Coast. There's some hot spots as well. And that's off the coast of Victoria, Tasmania.

NARRATION
Sea temperatures here off Tasmania have risen an astounding 2.28 degrees. That's about four times the global ocean average.

Dr Karl Braganza
And we think that's got something to do with changes in the East Australian Current, but we're not exactly sure why.

NARRATION
And, last year, West Australia's blood began to boil. Time to visit my childhood home. I'm a Cottosloe girl, Which means I grew up not noticing how wide the verges are...

Dr Jonica Newby
You can fit a whole Sydney house on this verge!

NARRATION
..and dodging sharks on my local beach. And over there is Rottnest - Perth's playground.

Dr Jonica Newby
I think I've swum in just about every rock pool round here. And, look, the water was lovely and warm. But what I'm about to tell you shocks me. Last year, on 28th February, the water in here hit 26.4 degrees. 26.4 degrees?! That's ridiculous.

NARRATION
It killed the coral.

Dr Jonica Newby
And has that ever happened here at Rottnest?

Dr Damian Thompson
Not that we're aware of. Not in 40 metres of water.

NARRATION
In fact, it was part of the biggest heatwave to hit Australia's waters ever. It began just north of Ningaloo Reef, hitting it heartbreakingly with the force of a pot of boiling oil.

Dr Damian Thompson
In some places, up to 80% of what was there before is now no longer there.

Dr Jonica Newby
Really just gone. Dead. So that's it.

Dr Damian Thompson
Gone, dead, yeah. Covered in algae.

NARRATION
It travelled 1,200km south, reaching all the way to the southernmost tip of WA.

Dr Jonica Newby
Apparently, whale sharks were seen off Albany! Is that right?

Dr Damian Thompson
Mm. Mm.

Dr Jonica Newby
Whale sharks! Do you know how far south Albany is? That is not whale shark country. That is white shark country!

NARRATION
Not that it's a laughing matter for the whale sharks.

Dr James Moore
They're effectively outrunning the hot water in search of cooler water and bait and feed to actually sustain them through that period.

NARRATION
The whole event lasted five months. It's our most extreme hot-water event on record.

Dr Jonica Newby
So there's actually something significant we should know about these rises that we've seen in sea temperature?

Dr Karl Braganza

Yeah, absolutely. Changes in ocean temperature around Australia really impact on the type of weather we receive.

Dr Jonica Newby
So, the warmer the water...?

Dr Karl Braganza
The warmer the water, generally the more rainfall that you'd expect.

Dr Jonica Newby
Well, still on our nation's circulation, what 100-year health check would be complete without blood pressure? I may be stretching the medical metaphor a little bit here, but I'm talking about sea level.

NARRATION
This is the glorious old West Australian port town of Fremantle. And it's home to one of Australia's oldest continuous tide gauge records.

Dr Jonica Newby
So this is the original Fremantle port's tidal gauge from 1897. Beautiful piece of machinery, isn't it?

And this is the latest tidal gauge. And, between them, what they chart is on average a 1.5mm rise per year since 1900.

NARRATION
Now, many of you may already be doing the maths on what that amounts to over 110 years. But, while you do that, I'm jumping back to the bottom of Australia - to Tassie's infamous Port Arthur, where there's a fantastic old marking that will answer that question. In 1841, the local storekeeper put in a tide mark, the oldest scientific one in the country.

Dr John Hunter
OK. It's just down there. There's a little...

Dr Jonica Newby
Oh! Right.

Dr John Hunter
..horizontal line with an arrow pointing down towards it.

Dr Jonica Newby
Yeah.

NARRATION
When the original records were rediscovered just a decade ago, Dr John Hunter was able to work out what's happened.

Dr John Hunter
OK, the total sea-level rise since 1841...

Dr Jonica Newby
Yeah.

Dr John Hunter
..is about 17 centimetres. And that's the length of that...

DrJonica Newby
Yeah?

Dr John Hunter
..that stick. If you compare that with Fremantle...

Dr Jonica Newby
Yep.

Dr John Hunter
..on the other side of the country, about 17 centimetres again since 1897.

Dr Jonica Newby
1897? OK, so that is a 100-year record, really, for Australia.

Dr John Hunter
Pretty well, yep, yep.

Dr Jonica Newby
This is how much it's gone up.

Dr John Hunter
Yep.

Dr Jonica Newby
17cm.

NARRATION
And this seemingly small rise has dramatically changed flooding. Last year, Port Arthur copped it like never before.

NARRATION
Using the historic Australian records, John Hunter has been able to show just how much each 10 centimetres rise in sea level has contributed to events like this.

Dr John Hunter

So, if you raise sea level by just 10 centimetres...

Dr Jonica Newby
Yeah.

Dr John Hunter
..you find you get a tripling of the number of flooding events.

Dr Jonica Newby
A tripling?

Dr John Hunter
And if you raise it by another 10 centimetres, it goes up by another factor of three, so that's a total of nine.

Dr Jonica Newby
So... so we've got nine times, effectively, the number of flooding events for structures at sea level than we did 100 years ago?

Dr John Hunter
Yes. That's right.

Dr Jonica Newby
I am surprised by that.

Dr John Hunter
It's a big change, yep.

Dr Jonica Newby
Yeah.

Dr Jonica Newby
So these are our current 'blood pressure', AKA 'sea level', readings. How are they looking?

Dr Karl Braganza
So what we're looking at here is basically from the satellite record from 1993. And we can see sea levels have risen everywhere. Red on this part up the top of the continent is a lot of sea-level rise. And the blue parts down the bottom is where we've had rather less sea-level rise.

NARRATION
Sea level naturally goes up and down a lot from year to year, but we can see from the Fremantle record the trend line is relentless.

Dr Jonica Newby
Which brings us last but not least to the final round of our 100-year health check - assessing our

nation's state of hydration.

NARRATION
Well, lately, parts of Australia have been well hydrated. Overhydrated, in fact. My personal assessment is that it's barely stopped raining in the last two years. My cottage has sprung a leak.

Dr Jonica Newby
I'm thinking of calling it 'Newby Creek'.

NARRATION
Our dams around Sydney and Brisbane are full. And there have been record-breaking floods... in Brisbane, Victoria, New South Wales. But, again, IS it new? What do the trusty old rain gauges from the bureau say?

Dr Jonica Newby
So, now, the last two years' rainfall have been quite extraordinary, haven't they?

Dr Karl Braganza
They have. They've been record-breaking. So, over the last 24-month period, the two years, we've seen more rainfall in Australia for a 24-month period than we've ever seen in the historical record.

Dr Jonica Newby
And tell me - does this have something to do with the fact that the ocean and the air temperatures are higher?

Dr Karl Braganza
Normally, when you get a La Nina event you'll get almost record rainfall in Australia. This time, what we saw was record sea-surface temperatures around Australia. And so we've got basically a perfect storm. We've got a La Nina event. We've got global warming going on in the oceans around Australia. And then we've got this record rainfall as well.

NARRATION
But you'll see there's one part of Australia noticeably absent from this acute attack of fluid retention. It's my old stamping ground - the south-west of WA... which is where I am now, down amongst the karri trees. Well, underneath them, actually - inside glorious Jewel Cave.

Dr Jonica Newby
OK, so this is what I came here to show you. You see this black line? That's actually a water line, the high water mark from the late '60s. This was once a lake. Up to here. But, ever since then, the water has just drained away.

NARRATION
The last of the water disappeared by the year 2000. And it's the same sad story across the region. The caves of Margaret River have lost their lakes and streams. Land use changes have compounded the problem, but this is a symptom of chronic dehydration.

Dr Karl Braganza
So what we've got here is basically rainfall during April to November. And, in the last 15 years, in particular in the south-east of the continent, here, is about a 10% to 20% reduction in that rainfall.

Dr Jonica Newby
That much, yeah.

Dr Karl Braganza
That's right. And over here in the west we've seen the same thing, but that's actually occurred since about 1970, so they've had almost about four decades with much less winter rainfall than they used to have.

NARRATION
And now the big summary. What has happened to our weather?

Dr Jonica Newby
Well, we're ready for the final report in Australia's 100-year health check. So, hydration?

Dr Karl Braganza
Wetting up north, in the Tropics. Longer-term dehydration across the south, particularly in south-west WA.

Dr Jonica Newby
OK. Circulation?

Dr Karl Braganza
Sea level's increasing all around Australia. Um... not lapping at our toes yet.

Dr Jonica Newby
Finally - temperature.

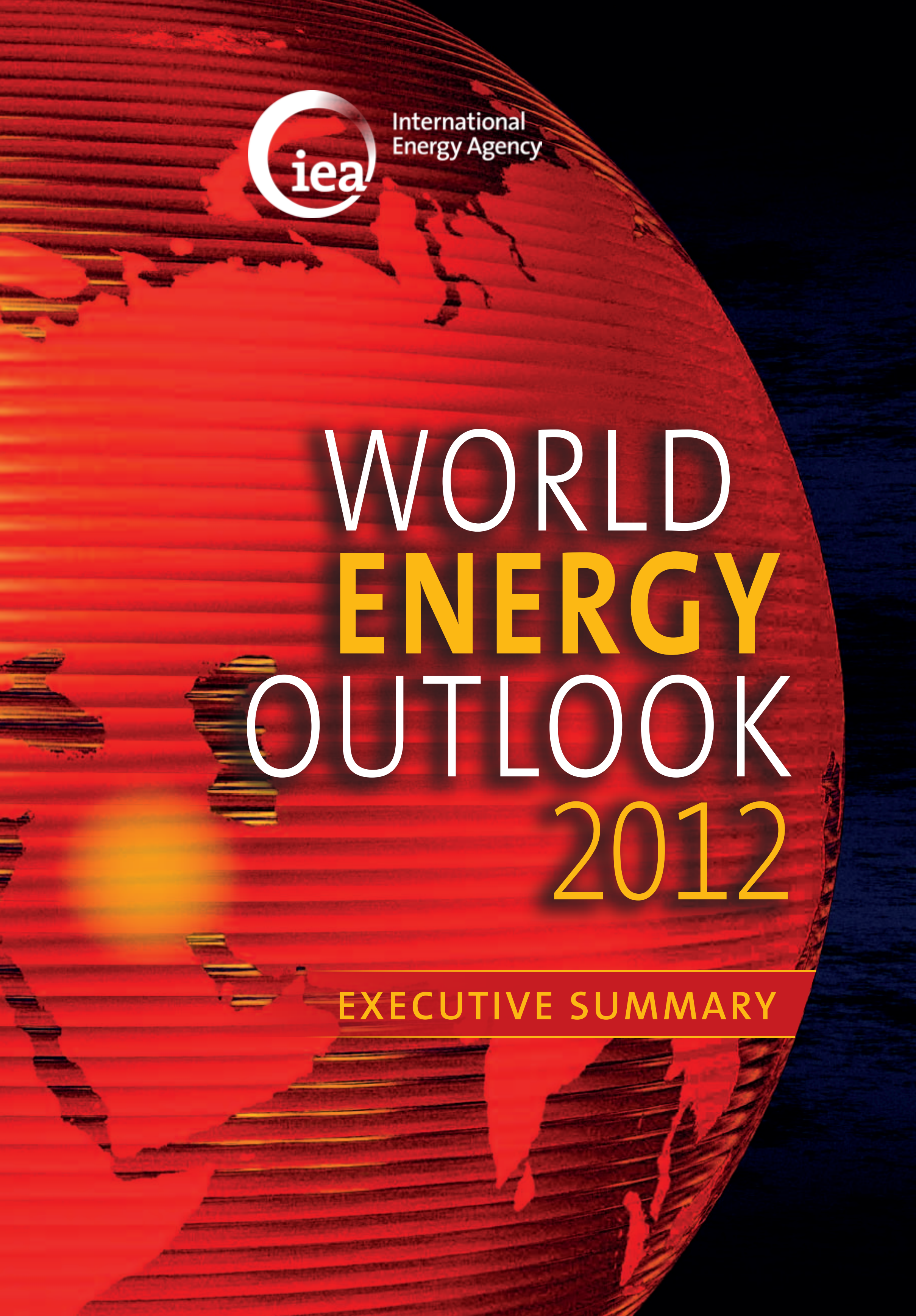
Dr Karl Braganza
Temperatures around Australia have risen by about a degree. Um, less chills, more fevers. And some regional variation in that as well. So some regions are heating up more than others.

NARRATION
Essentially, what the records show is that global warming isn't something that's coming - it's here in our backyards already. It's pointless now to ask, 'Is this climate change or natural variability?' What we see is one acting on top of the other.

Dr Karl Braganza
So, every parcel of air, every ocean current, every weather system is now about a degree warmer. And when you go through and do the physics, that's actually a hell of a lot of energy added to the climate system in general.

Dr Jonica Newby
You know, of all the things I learned on this investigation, it was that comment from Karl that really struck me. It was like, 'Aha! I finally get it.' There's one degree of extra heat across the whole planet. That's just a lot of new energy in our weather system. What happens when you add another degree? And another?

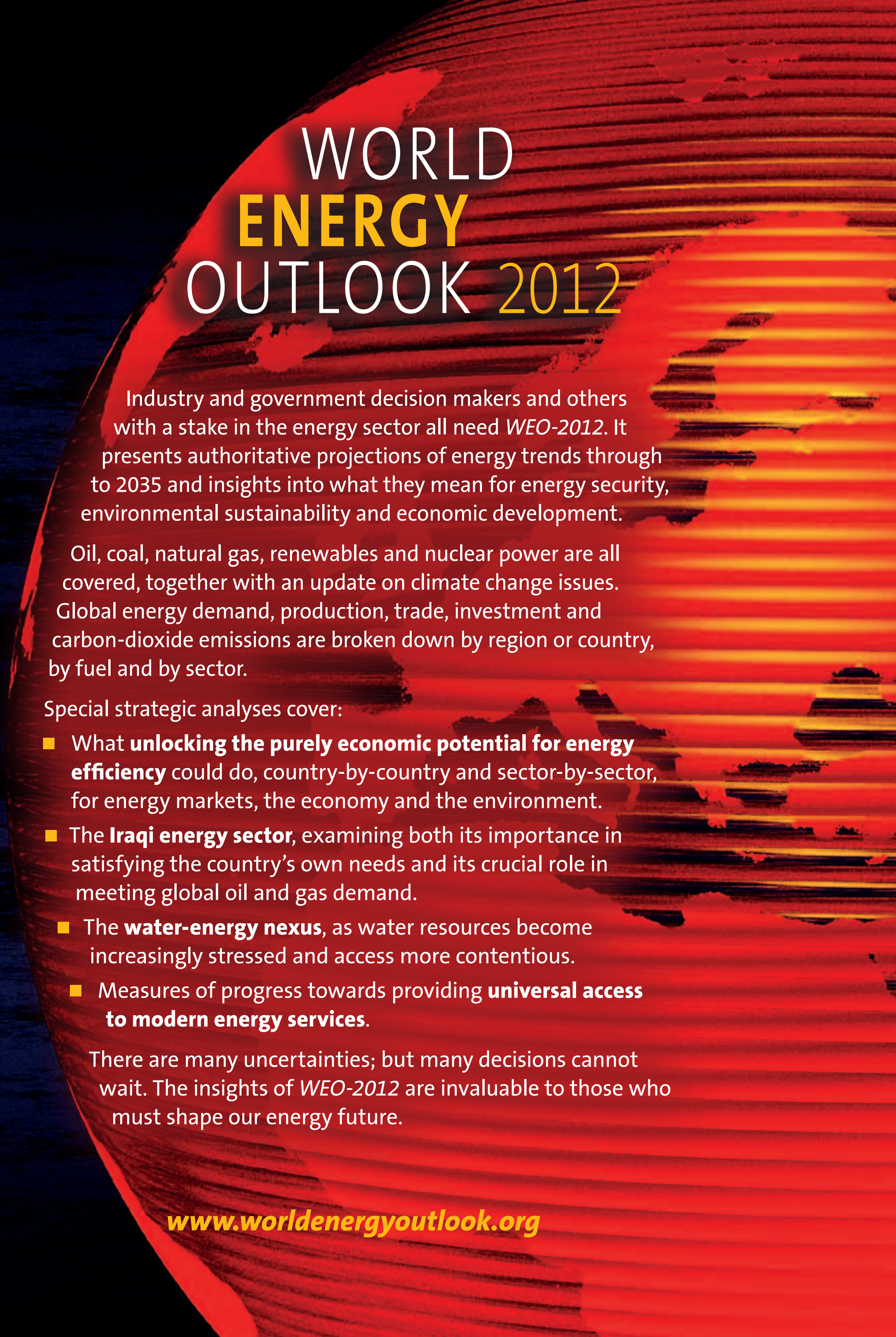
NARRATION
So what WILL happen in the future? Well, I'm obviously going to have to spend some money on a retaining wall. And, like the rest of us, I'll try to do my bit. But I'll continue to toast my sunset, pray to my snow gods and get as much joy as I always have out of the parts of Australia I love. I do think I should do so with eyes wide open, though, and not pretend there's no change to see.



International
Energy Agency

WORLD ENERGY OUTLOOK 2012

EXECUTIVE SUMMARY



WORLD ENERGY OUTLOOK 2012

Industry and government decision makers and others with a stake in the energy sector all need *WEO-2012*. It presents authoritative projections of energy trends through to 2035 and insights into what they mean for energy security, environmental sustainability and economic development.

Oil, coal, natural gas, renewables and nuclear power are all covered, together with an update on climate change issues. Global energy demand, production, trade, investment and carbon-dioxide emissions are broken down by region or country, by fuel and by sector.

Special strategic analyses cover:

- What **unlocking the purely economic potential for energy efficiency** could do, country-by-country and sector-by-sector, for energy markets, the economy and the environment.
- The **Iraqi energy sector**, examining both its importance in satisfying the country's own needs and its crucial role in meeting global oil and gas demand.
- The **water-energy nexus**, as water resources become increasingly stressed and access more contentious.
- Measures of progress towards providing **universal access to modern energy services**.

There are many uncertainties; but many decisions cannot wait. The insights of *WEO-2012* are invaluable to those who must shape our energy future.

www.worldenergyoutlook.org

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea (Republic of)
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission
also participates in
the work of the IEA.

International
Energy Agency

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A new global energy landscape is emerging

The global energy map is changing, with potentially far-reaching consequences for energy markets and trade. It is being redrawn by the resurgence in oil and gas production in the United States and could be further reshaped by a retreat from nuclear power in some countries, continued rapid growth in the use of wind and solar technologies and by the global spread of unconventional gas production. Perspectives for international oil markets hinge on Iraq's success in revitalising its oil sector. If new policy initiatives are broadened and implemented in a concerted effort to improve global energy efficiency, this could likewise be a game-changer. On the basis of global scenarios and multiple case studies, this *World Energy Outlook* assesses how these new developments might affect global energy and climate trends over the coming decades. It examines their impact on the critical challenges facing the energy system: to meet the world's ever-growing energy needs, led by rising incomes and populations in emerging economies; to provide energy access to the world's poorest; and to bring the world towards meeting its climate change objectives.

Taking all new developments and policies into account, the world is still failing to put the global energy system onto a more sustainable path. Global energy demand grows by more than one-third over the period to 2035 in the New Policies Scenario (our central scenario), with China, India and the Middle East accounting for 60% of the increase. Energy demand barely rises in OECD countries, although there is a pronounced shift away from oil, coal (and, in some countries, nuclear) towards natural gas and renewables. Despite the growth in low-carbon sources of energy, fossil fuels remain dominant in the global energy mix, supported by subsidies that amounted to $523 billion in 2011, up almost 30% on 2010 and six times more than subsidies to renewables. The cost of fossil-fuel subsidies has been driven up by higher oil prices; they remain most prevalent in the Middle East and North Africa, where momentum towards their reform appears to have been lost. Emissions in the New Policies Scenario correspond to a long-term average global temperature increase of 3.6 °C.

The tide turns for US energy flows

Energy developments in the United States are profound and their effect will be felt well beyond North America – and the energy sector. The recent rebound in US oil and gas production, driven by upstream technologies that are unlocking light tight oil and shale gas resources, is spurring economic activity – with less expensive gas and electricity prices giving industry a competitive edge – and steadily changing the role of North America in global energy trade. By around 2020, the United States is projected to become the largest global oil producer (overtaking Saudi Arabia until the mid-2020s) and starts to see the impact of new fuel-efficiency measures in transport. The result is a continued fall in US oil imports, to the extent that North America becomes a net oil exporter around 2030. This accelerates the switch in direction of international oil trade towards Asia, putting a focus on the security of the strategic routes that bring Middle East oil to Asian markets. The

United States, which currently imports around 20% of its total energy needs, becomes all but self-sufficient in net terms – a dramatic reversal of the trend seen in most other energy-importing countries.

But there is no immunity from global markets

No country is an energy "island" and the interactions between different fuels, markets and prices are intensifying. Most oil consumers are used to the effects of worldwide fluctuations in price (reducing its oil imports will not insulate the United States from developments in international markets), but consumers can expect to see growing linkages in other areas. A current example is how low-priced natural gas is reducing coal use in the United States, freeing up coal for export to Europe (where, in turn, it has displaced higher-priced gas). At its lowest level in 2012, natural gas in the United States traded at around one-fifth of import prices in Europe and one-eighth of those in Japan. Going forward, price relationships between regional gas markets are set to strengthen as liquefied natural gas trade becomes more flexible and contract terms evolve, meaning that changes in one part of the world are more quickly felt elsewhere. Within individual countries and regions, competitive power markets are creating stronger links between gas and coal markets, while these markets also need to adapt to the increasing role of renewables and, in some cases, to the reduced role of nuclear power. Policy makers looking for simultaneous progress towards energy security, economic and environmental objectives are facing increasingly complex – and sometimes contradictory – choices.

A blueprint for an energy-efficient world

Energy efficiency is widely recognised as a key option in the hands of policy makers but current efforts fall well short of tapping its full economic potential. In the last year, major energy-consuming countries have announced new measures: China is targeting a 16% reduction in energy intensity by 2015; the United States has adopted new fuel-economy standards; the European Union has committed to a cut of 20% in its 2020 energy demand; and Japan aims to cut 10% from electricity consumption by 2030. In the New Policies Scenario, these help to speed up the disappointingly slow progress in global energy efficiency seen over the last decade. But even with these and other new policies in place, a significant share of the potential to improve energy efficiency – four-fifths of the potential in the buildings sector and more than half in industry – still remains untapped.

Our Efficient World Scenario shows how tackling the barriers to energy efficiency investment can unleash this potential and realise huge gains for energy security, economic growth and the environment. These gains are not based on achieving any major or unexpected technological breakthroughs, but just on taking actions to remove the barriers obstructing the implementation of energy efficiency measures that are economically viable. Successful action to this effect would have a major impact on global energy and climate trends, compared with the New Policies Scenario. The growth in global primary energy demand to 2035 would be halved. Oil demand would peak just before 2020 and would be almost 13 mb/d lower by 2035, a reduction equal to the current production of Russia and

Norway combined, easing the pressure for new discoveries and development. Additional investment of $11.8 trillion (in year-2011 dollars) in more energy-efficient technologies would be more than offset by reduced fuel expenditures. The accrued resources would facilitate a gradual reorientation of the global economy, boosting cumulative economic output to 2035 by $18 trillion, with the biggest gross domestic product (GDP) gains in India, China, the United States and Europe. Universal access to modern energy would be easier to achieve and air quality improved, as emissions of local pollutants fall sharply. Energy-related carbon-dioxide (CO_2) emissions would peak before 2020, with a decline thereafter consistent with a long-term temperature increase of 3 °C.

We propose policy principles that can turn the Efficient World Scenario into reality. Although the specific steps will vary by country and by sector, there are six broad areas that need to be addressed. Energy efficiency needs to be made clearly visible, by strengthening the measurement and disclosure of its economic gains. The profile of energy efficiency needs to be raised, so that efficiency concerns are integrated into decision making throughout government, industry and society. Policy makers need to improve the affordability of energy efficiency, by creating and supporting business models, financing vehicles and incentives to ensure that investors reap an appropriate share of the rewards. By deploying a mix of regulations to discourage the least-efficient approaches and incentives to deploy the most efficient, governments can help push energy-efficient technologies into the mainstream. Monitoring, verification and enforcement activities are essential to realise expected energy savings. These steps would need to be underpinned by greater investment in energy efficiency governance and administrative capacity at all levels.

Energy efficiency can keep the door to 2 °C open for just a bit longer

Successive editions of this report have shown that the climate goal of limiting warming to 2 °C is becoming more difficult and more costly with each year that passes. Our 450 Scenario examines the actions necessary to achieve this goal and finds that almost four-fifths of the CO_2 emissions allowable by 2035 are already locked-in by existing power plants, factories, buildings, etc. If action to reduce CO_2 emissions is not taken before 2017, all the allowable CO_2 emissions would be locked-in by energy infrastructure existing at that time. Rapid deployment of energy-efficient technologies – as in our Efficient World Scenario – would postpone this complete lock-in to 2022, buying time to secure a much-needed global agreement to cut greenhouse-gas emissions.

No more than one-third of proven reserves of fossil fuels can be consumed prior to 2050 if the world is to achieve the 2 °C goal, unless carbon capture and storage (CCS) technology is widely deployed. This finding is based on our assessment of global "carbon reserves", measured as the potential CO_2 emissions from proven fossil-fuel reserves. Almost two-thirds of these carbon reserves are related to coal, 22% to oil and 15% to gas. Geographically, two-thirds are held by North America, the Middle East, China and Russia. These findings underline the importance of CCS as a key option to mitigate CO_2 emissions, but its pace of deployment remains highly uncertain, with only a handful of commercial-scale projects currently in operation.

Trucks deliver a large share of oil demand growth

Growth in oil consumption in emerging economies, particularly for transport in China, India and the Middle East, more than outweighs reduced demand in the OECD, pushing oil use steadily higher in the New Policies Scenario. Oil demand reaches 99.7 mb/d in 2035, up from 87.4 mb/d in 2011, and the average IEA crude oil import price rises to $125/barrel (in year-2011 dollars) in 2035 (over $215/barrel in nominal terms). The transport sector already accounts for over half of global oil consumption, and this share increases as the number of passenger cars doubles to 1.7 billion and demand for road freight rises quickly. The latter is responsible for almost 40% of the increase in global oil demand: oil use for trucks – predominantly diesel – increases much faster than that for passenger vehicles, in part because fuel-economy standards for trucks are much less widely adopted.

Non-OPEC oil output steps up over the current decade, but supply after 2020 depends increasingly on OPEC. A surge in unconventional supplies, mainly from light tight oil in the United States and oil sands in Canada, natural gas liquids, and a jump in deepwater production in Brazil, push non-OPEC production up after 2015 to a plateau above 53 mb/d, from under 49 mb/d in 2011. This is maintained until the mid-2020s, before falling back to 50 mb/d in 2035. Output from OPEC countries rises, particularly after 2020, bringing the OPEC share in global production from its current 42% up towards 50% by 2035. The net increase in global oil production is driven entirely by unconventional oil, including a contribution from light tight oil that exceeds 4 mb/d for much of the 2020s, and by natural gas liquids. Of the $15 trillion in upstream oil and gas investment that is required over the period to 2035, almost 30% is in North America.

Much is riding on Iraq's success

Iraq makes the largest contribution by far to global oil supply growth. Iraq's ambition to expand output after decades of conflict and instability is not limited by the size of its resources or by the costs of producing them, but will require co-ordinated progress all along the energy supply chain, clarity on how Iraq plans to derive long-term value from its hydrocarbon wealth and successful consolidation of a domestic consensus on oil policy. In our projections, oil output in Iraq exceeds 6 mb/d in 2020 and rises to more than 8 mb/d in 2035. Iraq becomes a key supplier to fast-growing Asian markets, mainly China, and the second-largest global exporter by the 2030s, overtaking Russia. Without this supply growth from Iraq, oil markets would be set for difficult times, characterised by prices that are almost $15/barrel higher than the level in the New Policies Scenario by 2035.

Iraq stands to gain almost $5 trillion in revenue from oil exports over the period to 2035, an annual average of $200 billion, and an opportunity to transform the country's prospects. The energy sector competes with a host of other spending needs in Iraq, but one urgent priority is to catch up and keep pace with rising electricity demand: if planned new capacity is delivered on time, grid-based electricity generation will be sufficient to meet peak demand by around 2015. Gathering and processing associated gas – much of which is currently flared – and developing non-associated gas offers the promise of a more efficient gas-fuelled power sector and, once domestic demand is satisfied, of gas exports. Translating oil export receipts into greater prosperity will require strengthened institutions, both to ensure efficient, transparent management of revenues and spending, and to set the course necessary to encourage more diverse economic activity.

Different shades of gold for natural gas

Natural gas is the only fossil fuel for which global demand grows in all scenarios, showing that it fares well under different policy conditions; but the outlook varies by region. Demand growth in China, India and the Middle East is strong: active policy support and regulatory reforms push China's consumption up from around 130 billion cubic metres (bcm) in 2011 to 545 bcm in 2035. In the United States, low prices and abundant supply see gas overtake oil around 2030 to become the largest fuel in the energy mix. Europe takes almost a decade to get back to 2010 levels of gas demand: the growth in Japan is similarly limited by higher gas prices and a policy emphasis on renewables and energy efficiency.

Unconventional gas accounts for nearly half of the increase in global gas production to 2035, with most of the increase coming from China, the United States and Australia. But the unconventional gas business is still in its formative years, with uncertainty in many countries about the extent and quality of the resource base. As analysed in a *World Energy Outlook Special Report* released in May 2012, there are also concerns about the environmental impact of producing unconventional gas that, if not properly addressed, could halt the unconventional gas revolution in its tracks. Public confidence can be underpinned by robust regulatory frameworks and exemplary industry performance. By bolstering and diversifying sources of supply, tempering demand for imports (as in China) and fostering the emergence of new exporting countries (as in the United States), unconventional gas can accelerate movement towards more diversified trade flows, putting pressure on conventional gas suppliers and on traditional oil-linked pricing mechanisms for gas.

Will coal remain a fuel of choice?

Coal has met nearly half of the rise in global energy demand over the last decade, growing faster even than total renewables. Whether coal demand carries on rising strongly or changes course will depend on the strength of policy measures that favour lower-emissions energy sources, the deployment of more efficient coal-burning technologies and, especially important in the longer term, CCS. The policy decisions carrying the most weight for the global coal balance will be taken in Beijing and New Delhi – China and India account for almost three-quarters of projected non-OECD coal demand growth (OECD coal use declines). China's demand peaks around 2020 and is then steady to 2035; coal use in India continues to rise and, by 2025, it overtakes the United States as the world's second-largest user of coal. Coal trade continues to grow to 2020, at which point India becomes the largest net importer of coal, but then levels off as China's imports decline. The sensitivity of these trajectories to changes in policy, the development of alternative fuels (*e.g.* unconventional gas in China) and the timely availability of infrastructure, create much uncertainty for international steam coal markets and prices.

If nuclear falls back, what takes its place?

The world's demand for electricity grows almost twice as fast as its total energy consumption, and the challenge to meet this demand is heightened by the investment needed to replace ageing power sector infrastructure. Of the new generation capacity that is built to 2035, around one-third is needed to replace plants that are retired. Half of all new capacity is based on renewable sources of energy, although coal remains the leading global fuel for power generation. The growth in China's electricity demand over the period to 2035 is greater than total current electricity demand in the United States and Japan. China's coal-fired output increases almost as much as its generation from nuclear, wind and hydropower combined. Average global electricity prices increase by 15% to 2035 in real terms, driven higher by increased fuel input costs, a shift to more capital-intensive generating capacity, subsidies to renewables and CO_2 pricing in some countries. There are significant regional price variations, with the highest prices persisting in the European Union and Japan, well above those in the United States and China.

The anticipated role of nuclear power has been scaled back as countries have reviewed policies in the wake of the 2011 accident at the Fukushima Daiichi nuclear power station. Japan and France have recently joined the countries with intentions to reduce their use of nuclear power, while its competitiveness in the United States and Canada is being challenged by relatively cheap natural gas. Our projections for growth in installed nuclear capacity are lower than in last year's *Outlook* and, while nuclear output still grows in absolute terms (driven by expanded generation in China, Korea, India and Russia), its share in the global electricity mix falls slightly over time. Shifting away from nuclear power can have significant implications for a country's spending on imports of fossil fuels, for electricity prices and for the level of effort needed to meet climate targets.

Renewables take their place in the sun

A steady increase in hydropower and the rapid expansion of wind and solar power has cemented the position of renewables as an indispensable part of the global energy mix; by 2035, renewables account for almost one-third of total electricity output. Solar grows more rapidly than any other renewable technology. Renewables become the world's second-largest source of power generation by 2015 (roughly half that of coal) and, by 2035, they approach coal as the primary source of global electricity. Consumption of biomass (for power generation) and biofuels grows four-fold, with increasing volumes being traded internationally. Global bioenergy resources are more than sufficient to meet our projected biofuels and biomass supply without competing with food production, although the land-use implications have to be managed carefully. The rapid increase in renewable energy is underpinned by falling technology costs, rising fossil-fuel prices and carbon pricing, but mainly by continued subsidies: from $88 billion globally in 2011, they rise to nearly $240 billion in 2035. Subsidy measures to support new renewable energy projects need to be adjusted over time as capacity increases and as the costs of renewable technologies fall, to avoid excessive burdens on governments and consumers.

A continuing focus on the goal of universal energy access

Despite progress in the past year, nearly 1.3 billion people remain without access to electricity and 2.6 billion do not have access to clean cooking facilities. Ten countries – four in developing Asia and six in sub-Saharan Africa – account for two-thirds of those people without electricity and just three countries – India, China and Bangladesh – account for more than half of those without clean cooking facilities. While the Rio+20 Summit did not result in a binding commitment towards universal modern energy access by 2030, the UN Year of Sustainable Energy for All has generated welcome new commitments towards this goal. But much more is required. In the absence of further action, we project that nearly one billion people will be without electricity and 2.6 billion people will still be without clean cooking facilities in 2030. We estimate that nearly $1 trillion in cumulative investment is needed to achieve universal energy access by 2030.

We present an Energy Development Index (EDI) for 80 countries, to aid policy makers in tracking progress towards providing modern energy access. The EDI is a composite index that measures a country's energy development at the household and community level. It reveals a broad improvement in recent years, with China, Thailand, El Salvador, Argentina, Uruguay, Vietnam and Algeria showing the greatest progress. There are also a number of countries whose EDI scores remain low, such as Ethiopia, Liberia, Rwanda, Guinea, Uganda and Burkina Faso. The sub-Saharan Africa region scores least well, dominating the lower half of the rankings.

Energy is becoming a thirstier resource

Water needs for energy production are set to grow at twice the rate of energy demand. Water is essential to energy production: in power generation; in the extraction, transport and processing of oil, gas and coal; and, increasingly, in irrigation for crops used to produce biofuels. We estimate that water withdrawals for energy production in 2010 were 583 billion cubic metres (bcm). Of that, water consumption – the volume withdrawn but not returned to its source – was 66 bcm. The projected rise in water consumption of 85% over the period to 2035 reflects a move towards more water-intensive power generation and expanding output of biofuels.

Water is growing in importance as a criterion for assessing the viability of energy projects, as population and economic growth intensify competition for water resources. In some regions, water constraints are already affecting the reliability of existing operations and they will increasingly impose additional costs. In some cases, they could threaten the viability of projects. The vulnerability of the energy sector to water constraints is widely spread geographically, affecting, among others, shale gas development and power generation in parts of China and the United States, the operation of India's highly water-intensive fleet of power plants, Canadian oil sands production and the maintenance of oil-field pressures in Iraq. Managing the energy sector's water vulnerabilities will require deployment of better technology and greater integration of energy and water policies.

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