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Linkages Between Clean Technology Development and Environmental Health Outcomes in Regional Australia

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1. Introduction

1.1 What is 'cleantech'?

By technical definition, clean technology (also referred to as 'cleantech' or 'eco-innovation') reflects 'a diverse range of technologies, products, services and processes that measure, reduce, eliminate or remediate negative environmental impact, and/or improve the productive and responsible use of natural resources while returning a profit to the provider' (DEEDI 2010). However, more simply defined, a clean technology practice, product or industry is typically one that combines the three essential components of efficiency, environmental outcomes, and profitability. Consequently, the focus for clean technology development is usually about the simultaneous pursuit of increased profitability as well as environmental benefit.

1.2 Current status of the cleantech industry

At the global level, clean technology is being embraced across all business and industry sectors. Indeed, 'cleantech' is now often considered as an industry in its own right. In 2010, the Australian cleantech review identified a number of national cleantech industry sub-sectors, including renewable energy, water, waste and recycling, energy efficiency, carbon trading and environmental services (ACT, 2010). At the global scale, significant investment in cleantech is already occurring in both developing and developed economies; with the Americas, Asia and – to a lesser extent – Europe dominating the market in terms of venture capital expenditure (ACT, 2010; 2011; Cleantech Group 2011). The Australian clean technology industry is still emerging, but it is a rapidly growing sector: in 2011, Australian cleantech companies had combined revenue of $22 billion, and employed over 25,000 people (ACT, 2010). This represents more than doubling in the value of the sector as well as an increase of some 12,000 jobs since 2010 (ACT 2010). Recent data show that the national emphasis in cleantech is currently centred on solar, energy efficiency and transport technologies (ACT, 2011). These trends largely mirror those at the global level, where energy efficiency, solar, biofuels and recycling are capturing large investment and interest (Cleantech Group 2011). It is more than coincidental that it is these same industries who are leading the way in terms of transiting countries to a lower-carbon and more environmentally sustainable future: the ongoing policy and economic focus on this area means that ‘cleantech’ is likely to continue to experience strong growth. Consequently, it will be important that the risks and benefits of this sector be well understood and managed.

1.2.1 The role and importance of ‘cleantech’ to regional Australia

Australia’s regional areas are vital in helping to deliver national goals in social, economic and environmental issues, and they have strong drivers to be sustainable: regional communities represent an important and complex nexus between climate change, population growth, regionalisation, business and industry growth, natural resource management, liveability and land use conflicts. However, many of Australia’s regions are facing an important challenge: where economic growth relies solely on industries that consume finite natural resources, a region’s economic position can only decline as those resources are extracted (Clement, 2000). Ecological concerns and issues of resource depletion have been largely absent from the management of regional economic development in Australia (Courvisanos, 2009, p. 256). There is now a need to change this trajectory, and establish new regional economies around ecosystem services which enable regional areas to recapture value and create market and consumption niches (Marsden, 2010). Clearly, ‘cleantech’ is one way of exploring this.

The value of clean technology to regional development has already been demonstrated with clean technology ‘hubs’ being established in a number of locations worldwide. These areas are characterised by a concentration of industry in one or more clean technology applications. For example, globally significant sites include Denmark (wind power), Jiangsu Province and Baoding in China (solar and biomass energy facilities), India and North Africa (solar power), and Abu Dhabi (a green/renewable energy consortium).

Australia is a developed and technological nation of strong economic standing and one which has the ability to offer a stable operating environment. It is richly endowed with natural resources; it also faces a number of key environmental challenges including those related to energy, water, waste and climate. There are many locations that could host significant developments in the cleantech arena, thus exploiting the natural advantages that Australian regions have for innovation and solving environmental challenges. There are also many factors to support the use of a regional approach to establish and grow Australian cleantech: these include the strong regional drivers for sustainability and the importance of regions in the national innovation agenda. Using a regional-level approach also brings cleaner production and environmental gains almost by default: for example, the recovery, reuse and/or substitution of raw input materials with locally sourced alternatives reduces transport emissions and encourages recycling (van Berkel, 2007). Furthermore, ‘green’ businesses and industries tend to be established in response to local markets for sustainable goods and services (Chapple and Hutson, 2010). Despite these features and benefits, remarkably few cleantech hubs (or clusters) are yet to exist in Australia. This is likely to change as the economic and environmental drivers for cleantech in regional Australia are increasingly recognised, and as policy imperatives in the areas of carbon, renewable energy targets and other sustainability goals are pursued. However, cleantech hubs are now beginning to be viewed not only for their commercial potential and their ability to respond to environmental challenges, but also for their ability to blend social challenges and issues into existing decision-making by industry (Horwitch and Mulloth, 2010). Perhaps one of the most important social elements of cleantech that is yet to be properly investigated and exploited is the possible effects on public and occupational environmental health outcomes.

2. Environmental health and industry in regional Australia

In 2006, the World Health Organisation (WHO) published estimates on the environmental burden of disease. Here, the WHO researchers attempted to determine the proportion of global disease that could be prevented through environmental modification, specifically with respect to the following:

- air, soil and water pollution with chemicals or biological agents;
- ultraviolet and ionising radiation;
- built environment;
- noise and electromagnetic fields;
- occupational risks;
- agricultural methods, including irrigation schemes;
- anthropogenic climate change and ecosystem degradation; and
- individual behaviours related to the environment, such as hand washing, food contamination with unsafe water or dirty hands.

According to the report, “an estimated 24% of the global disease burden and 23% of all deaths can be attributed to environmental factors”. As part of this research, the WHO has also published profiles for each of its member states, detailing the impact that environmental factors have on health in terms of deaths and disability adjusted life years (DALYs) lost. The figures for Australia indicate that outdoor air pollution is the most significant risk factor for environmentally related morbidity and mortality, with an estimated 700 deaths per annum and 0.2 DALYs /1,000 people/ year attributable to these exposures (WHO 2009).

Industry has long been known to adversely affect the health of communities living in surrounding regions. While it is clear that the entirety of the environmental burden of disease identified by the WHO cannot be attributed solely to industry, there is ample evidence to illustrate the significant effects that industrial activity can have upon human health. Perhaps the best known example of this is the fishing village of Minamata in Japan, where a chemical manufacturing plant released methylmercury-contaminated waste into the bay. The impacts were wide ranging, including severe neurological effects and birth defects as well as the effective destruction of the local fishing industry, the traditional basis of the town’s economy (Tsuda et al., 2009).

Australian examples of industry-linked health impacts include the excessive blood lead levels identified in children and adults residing in Australian smelter towns such as Mt Isa (Queensland Health 2008), Port Pirie (Wilson et al. 1986) and Broken Hill (Boreland & Lyle

2009). In these towns, the smelting process has released airborne lead for decades, resulting in significant levels of soil contamination. This has consequently led to a significant increase in blood lead level, particularly in children (Boreland & Lyle 2009; Queensland Health 2008; Wilson et al., 1986).

These examples are consistent with the results published by the WHO, indicating that industrial air pollution and the related deposition of contaminants is of concern with respect to the health of communities located in some industrialised regions of Australia. A report by the Bureau of Transport and Regional Economics (BTRE, 2005) also noted that rural and regional Australia is particularly challenged by managing windblown dust from mining and agriculture, including smoke and agricultural sprays. There are also a number of other environmental health outcomes in Australia that are impacted upon by industry, including:

- water quality, particularly natural aquifers: for example, recent growth in the development of the coal seam gas industry in central and south-eastern Queensland has been associated with groundwater contamination (Moran & daCosta 2011)
- noise and odour problems: complaints to environmental heath regulatory agencies often arise as a consequence of population growth into declining industrial areas. Unfortunately, the pre-existing industries tend to be older facilities with less investment in environmental controls, thus resulting in residents' exposure to odour, noise and pollutants.
- vapour intrusions: contamination of soil and groundwater by volatile organic compounds can be the result of spills, leaks and past disposal practices from previous industrial activity. These compounds can leak into dwellings built on past industrial sites through pores and cracks in soil and foundations and present a risk to the health of residents (Evans et al., 2010)

In addition to these, in the long term, anthropogenic climate change (i.e., that resulting from high levels of greenhouse gas emissions from industry) has been predicted to impact upon health in a variety of ways. Some examples include heat-related mortality and morbidity (e.g., heatstroke in the elderly); waterborne diseases relating to a reduction in water quality associated with reduced riverine flows; flood- related deaths, injuries and economic impacts relating to rainfall events of greater intensity; increased food-borne disease related to temperature increases and the spread of vector-borne disease, particularly dengue fever, Ross River virus infection and potentially malaria (McMichael et al., 2002).

3. Establishing cleantech hubs to help drive healthy regions

The basic relationship between emerging 'cleantech' industries and environmental health outcomes has been recognised for over a decade: it was succinctly described in 1998 by the World Resources Institute:

"A long-term strategy for preventing exposure to hazardous industrial pollutants is to reduce their use in the first place through cleaner production… industry must reduce raw material inputs – chemicals, natural resources, energy, water – and at the same time reduce air, water, and solid pollutants for each unit of production. This push toward cleaner production is typically driven by environmental and economic concerns rather than by health concerns, although it seems certain that cleaner production would benefit public health as well' (WRI et al., 1998, online source).

However, according to Briggs (2003), the actual associations between environmental pollution and health outcomes are complex and often poorly characterized. Partly, this may be due to the emerging nature of the 'cleantech' industry, but it is also likely to reflect the particularly complex nature of relationships between industry and environmental health. As Briggs noted, this is a difficult field of study with 'long latency times, the effects of cumulative exposures, and multiple exposures to different pollutants which might act synergistically' (Briggs, 2003, p. 1). For example, even the public health outcomes of a particular industry sub-sector may be contrasted by the different scales in developed compared with developing nations. A case in point is the clean technology that is being rapidly adopted by advanced nations (e.g., US, Japan), as well as in developing economies (China, India, Africa). The latter nations are likely to experience particularly strong environmental health benefits from this growth, since developing nations often experience high 'baseline' health risks from industrial pollution: this results from a lack of investment in modern technology, combined with less-stringent environmental regulations that allow high pollutant loads (Briggs, 2003).

Another difficulty in measuring the health impacts of clean technology are temporal and spatial influences. There are large differences in the nature and extent of the short-term health impacts (0-5 years) that might result from clean technology adoption, compared with those in the long-term (20+ years). For example, in the short-term, benefits may flow from reduced noise, water and air pollution burdens and the direct impacts of these would be relatively easy to measure. In one recent case, Hixson et al. (2010) performed modelling of emissions to 2030 in order to examine the likely public exposures to air pollution under different regional planning, land use and transportation scenarios. On the other hand, in the long-term, clean technology may contribute to climate change mitigation, thus driving vastly improved health outcomes. However, isolating and quantifying the specific role of 'clean' industries in achieving this would prove extremely difficult. Similarly, pinpointing the health benefits of large-scale industrial changes in (for example) air pollution will require a strong understanding of airshed issues and an appreciation of how a local area may be impacted by weather and other influences: pollutants (especially airborne materials) dissipate with distance, so human populations that are located more closely to the source will naturally experience greater impacts (US EPA, 2010).

These kinds of experimental and analytical difficulties means that the relationship(s) between clean technology development (clean, green business technologies and behaviours) and public health outcomes are poorly articulated, and are likely to remain so for some time. Nevertheless, the discussion below attempts to begin identifying some of keyways in which clean technology can impact upon environmental health outcomes, with respect to both the general population as well as the cleantech workforce.

3.1 Direct and indirect health benefits

There are a number of ways that development and/or adoption of cleantech technologies and practices can assist with improving environmental health outcomes, and these can be both direct and indirect. At its ultimate level, the development of clean technology industries may displace entire sectors (e.g., coal-fired power generation), thus removing the impacts associated with them either in the workplace, or in surrounding communities. For example, a study is already underway to examine the excess burden of respiratory disease, mental health disorders, cancer, injury and death that is associated with coal mining in the Hunter Valley and Liverpool Plains regions in Australia, including impacts on social health and sense of community. This work will help to identify the environmental health risks of the conventional resource industries, thereby helping to quantify the nature and extent of health benefits that could be expected when those operations are replaced with industries of a different 'cleantech' kind.

At a more modest level, introducing 'cleantech' into existing industries through retrofitting or changed operational and behavioural practices can also introduce employee and public health benefits. Where safer, less toxic, or non-toxic chemical alternatives can be identified and used in place of environmentally hazardous substances, a reduction in chemical waste and public exposures should follow (LCSP, 2010). A good example of this is the use of biofuels: Traviss et al. (2010) reported that employee health risks related to exhaust exposures were much lower when biodiesel blends were used to power heavy-duty equipment, compared with regular petroleum diesel. Industries that adopt cleantech principles may also be able to use existing industrial, commercial or domestic waste as process inputs (e.g., feedstock for bio-energy): this further reduces the public health burden associated with waste management from neighbouring sectors. As cleaner production technologies lead to greater efficiency in natural resource and energy use, they are also usually linked with decreases in the amounts and toxicity of generated waste products (Kohler, 1998). A key example of the reduction of air pollutants with clean energy generation, especially fine particulate matter (PM_{25}), volatile organic compounds and ozone, which have each been linked with both respiratory and cardiovascular illnesses and death (US EPA, 2010). Other benefits that may result from reduced pollution, disease and injury burdens as a result of new, clean industries are summarised in Table .

One of the most specific studies into the public health benefits of developing a 'cleantech' culture focussed not on the industrial sector, but instead on the advantages of energy efficiency initiatives in residential buildings. Wilksinson et al. (2009) reported that a mix of actions designed to improve the energy efficiency of UK housing stock would be associated with 850 fewer DALYs per million head of population in one year. The study concluded that there are therefore 'important co-benefits in pursuing health and climate goals' (Wilkinson et al., 2009, p. 1917).

In a more indirect sense, clean technology – through its focus on environmental efficiency – may lead to new techniques in impact assessment, life-cycle analysis, auditing and risk assessment: this helps to culture of awareness and understanding that can lead to reduced exposures in the workplace as well as the general community (Kohler, 1998). Moreover, even in the absence of process or technological changes, existing industries may be able to embrace cleantech by committing to greater environmental monitoring and reporting. This in itself may contribute to improved public health benefits in the long-term, through development of an evidence base that will allow a better understanding of the linkages between 'conventional' versus cleantech-based resource use or development and public

'Clean tech' practice (behaviour or technology adoption)	Possible environmental health benefits
Use of integrated pest management in place of synthetic agrichemicals	Reduced risk of non-target pesticide drift and related respiratory complaints
Agricultural best practice in land management	Reduced runoff and eutrophication, leading to reduced public health risk from toxic algal blooms
Better agricultural efficiencies and productivity	Improved food quality (higher nutritional content, decreased antibiotic use and reduced hormone loads).
Improved water efficiencies at the regional level	Reduced need for river regulation (dams and weirs), thus avoiding climbing salinity levels that are harmful to residents with high blood pressure or are on dialysis treatment.
Introduction of solar technology	Avoidance of cooling towers associated with conventional coal-fired technologies, thus decreasing the risk of harboured Legionnaire's disease.
Improved waste and wastewater management practices	Reduced the load of disease-carrying vectors and pollutants
Improved transport networks, use of regional supply chains	Decrease in regional nitrous oxide emissions

Table 1. Examples of direct human health benefits from adoption of clean technology practices

health. It may also assist in better preparedness and rapid response to environmental hazards on industrial sites. For example, combining wireless sensor networks with web-based real-time data reporting provides an efficient and powerful way to detect health hazards and respond accordingly (Morreale et al., 2010).

Investing in cleantech research and development can also have wider benefits. For example, in agriculture, it has recently been acknowledged that a greater understanding of microbial ecology within livestock will help with reducing greenhouse gas emissions from ruminants; and that these studies may also assist in a better understanding of human health complaints linked with microbial dysfunction (such as inflammatory bowel disease and obesity) (Frank, 2011). Furthermore, technological advances that are engineered for 'cleantech' purposes may also have spillover into health care and treatment: for example, installing high-reliability renewable energy systems in rural, regional and remote areas may enable the operation of advanced health infrastructure (e.g., sensitive health monitoring equipment). One final example of an indirect public health effect of clean technology innovation is the potential for new industries to drive regional job creation and economic growth. In turn, this can lift the unemployment rate and thus cause flow-on advantages in terms of overcoming the socio-economic disadvantage that is typically linked with poor health outcomes. Since it has been shown that that work can be beneficial for people's physical and emotional wellbeing (ABS, 2011), this is a positive public health result.

3.2 Environmental health risks of cleantech

Unfortunately, there may also be some disadvantages associated with cleantech in terms of public health risks. In Australia, the potentially negative health impacts of wind farms has attracted significant interest; with a recent Senate report being published on the potential social and economic impacts of these facilities (CARC, 2011). This document noted the potential for noise and vibration associated with individual wind turbines and/or wind-based generation facilities to be linked with ill health and poor quality of life. The reported health complaints have predominantly included sleep disturbance and fatigue, headaches, dizziness/vertigo, tinnitus, and ear pressure/pain (CARC, 2011). There has also been discussion on the potential for 'shadow flicker' (caused when sunlight is interrupted by the turbine blades) to be associated with seizures; and for turbines to cause unhealthy exposures to electromagnetic radiation (NHMRC, 2010). However, there continues to be questions over the scientific rigour of each of these claims, with a number of international studies opposing the view that noise, vibration or other aspects of wind farms are linked with health effects (be it either audible or inaudible) (NHRMC, 2010). The Australian senate report thus called for 'adequately resourced epidemiological and laboratory studies of the possible effects of wind farms on human health' to close this knowledge gap (CARC, 2011, p. 9).

There are also some technical (operational) aspects of 'cleantech' where environmentally friendly practices must be carefully deployed so that public health risks are minimized: here, wastewater reuse and recycling and of various solids wastes are two good examples. For example, alternative waste technology (AWT), which involves a range of waste treatment (e.g., incineration) and resource-recovery (e.g. recycling) activities, is an increasingly important part of clean technology systems. Within these, there are a range of complex materials handling and occupational health issues, such as concerns over odour, hazardous emissions, vermin and disease (Hamer, 2003). The re-use of purified wastewater to augment drinking water supplies carries with it a potential increase – albeit a slight one – in the incidence of some human diseases; it also requires additional electricity demand to operate reverse osmosis and ultraviolet disinfection systems as well as the use of chemicals for disinfection (Gardner et al., 2008). However, as many of these issues are also shared by traditional technologies, the use of clean technology in this sense does not necessarily introduce new environmental health risks, excepting facilities that bring new types of wastes (e.g., heavy metals) into the region for processing. This latter may be particularly important in the context of establishing e-waste recycling centres that may deal in regulated waste (e.g., mercury, lead).

4. A regional cleantech case study from Central Queensland

4.1 The Central Queensland region

Building comprehensive business cases for clean technology hubs in regional Australia will require data on not only the economic and environmental benefits that these initiatives can bring, but also the social wellbeing and human health advantages. The following case study therefore attempts to provide an evidence base for the latter, by identifying the likely environmental health implications of establishing a cleantech hub in the central Queensland region. For the purposes of this study, Central Queensland (CQ) will be taken to mean the Fitzroy statistical division, which is located on Queensland's central coast and extends for some way inland. Rockhampton is the major city in the region and other major localities include the industrial and mining areas of Gladstone and Emerald (Figure).

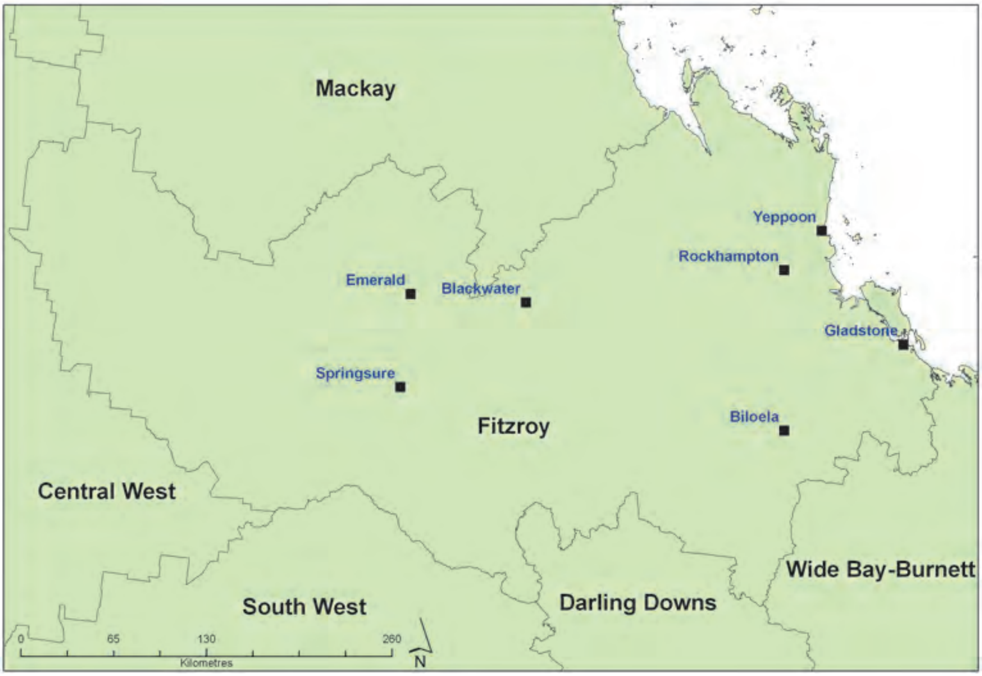

Fig. 1. The Fitzroy Statistical Division (Australian Standard Geographical Classification 2006). Source: provided on request from the Queensland Office of Economic and Statistical Research, Brisbane.

4.2 Climate conditions and climate change

Specific data on climate and climate projections can be difficult to source at the regional level in Queensland. However, with the threat of climate change, this is gradually improving. In 2009, a study by Kinnear et al. (2010) examined the available data for Central Queensland, with the objective of exploring climate change risk for local businesses. This study indicated that historically, CQ has experienced a subtropical climate with wet summers accompanied by low winter rainfall, and coastal areas experiencing a slightly milder climate compared with inland locations. However, the region is showing a warming trend, with hotter seasons (particularly spring and autumn), an increase in the number of days exceeding 35°C, and a decline in periods where temperatures are below 4°C (Fig. 2; Fig. 3). The region has also experienced a steady annual decline in total annual rainfall over the past two decades, but an increase in rainfall intensity (Kinnear et al., 2010).

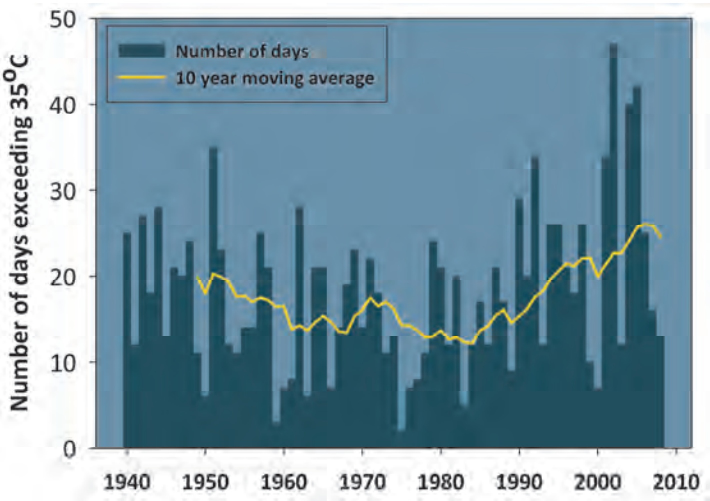

Fig. 2. Trend in the number of extremely hot days (exceeding 35°C) recorded at Rockhampton Aero monitoring station, 1940 to 2008 (adapted from BoM weather data).

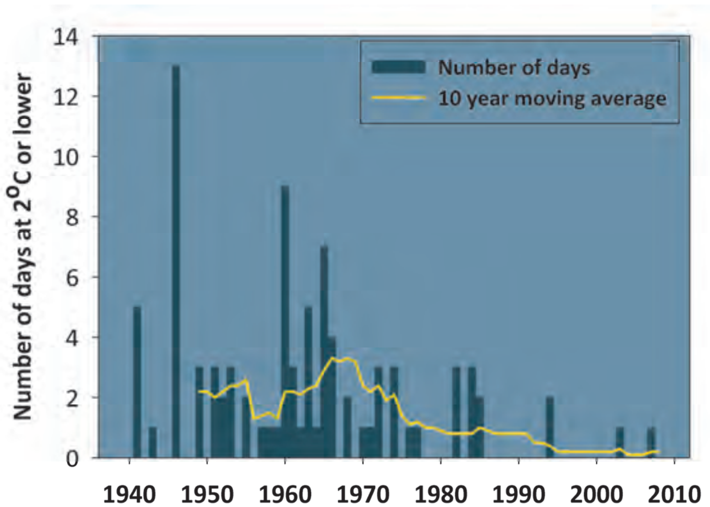

Fig. 3. Trend in the number of extremely cold days (2°C or lower) recorded at Rockhampton Aero monitoring station, 1940 to 2008 (adapted from BoM weather data).

Kinnear et al. (2010) also reported that current climate change modelling, specific for the Rockhampton region, shows that by 2030:

- the average annual temperature in the region is expected to rise by 1°C; and
- there will be a further decline of 50-100mm in annual rainfall (comprised of moderately increased late-summer rainfall and substantial decreases in the remaining three seasons).

A seasonal shift of approximately six weeks is also expected (e.g., ‘summer’ will be from January-March, rather than December-February); together with a sea-level rise of 18 – 59 cm along the Queensland coast (Kinnear et al., 2010).

4.3 Economic profile and key industry sectors

In economic terms, the key sectors in the Central Queensland regional economy are the mining, construction and manufacturing sectors, which together comprise some 63% of the economic output for the region (Fig.). However, retail trade, manufacturing, and health and community services are also key industries in terms of employment creation; whilst mining, manufacturing and property and business services contribute most significantly to the regional value-add (Fig.). Thus, Central Queensland has a diverse economy built on an array of different industries, each playing different, but important roles.

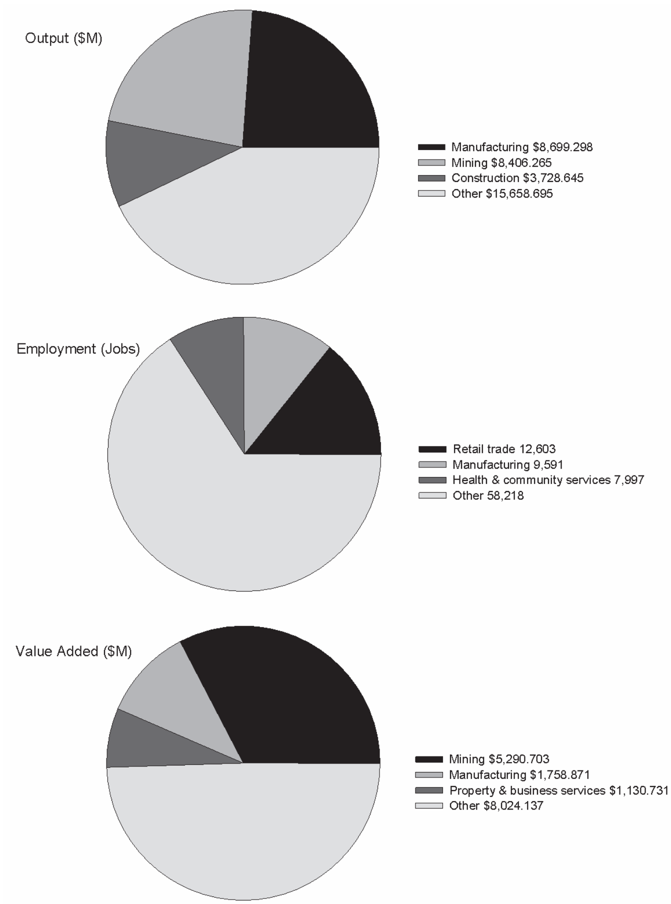

Fig. 4. Analysis of key contributing industries in the Central Queensland region (Fitzroy and Central West Statistical divisions) – economic output, employment, and value-added totals (as at June 2010). Source: REMPLAN Economic Modelling Tool.

4.4 Current and projected socio-demographic statistics

In addition to being an 'economic powerhouse' the CQ region houses a significant percentage of the state's population. The region will grow to 344,938 people by 2031, from a 2006 base population of 206,166 (Table). The region is currently experiencing a loss of young adults, but an increase in the aged population, and both these trends are set to continue (Table). Socio-demographic trends in the CQ population are heavily influenced by the presence of mining and other industrial activity in the Bowen Basin coal and energy reserves. The 2009 reported unemployment rate for Fitzroy statistical division was 5.0% (OESR, 2010). However, based on 2006 Census data[1], over 40% of employed males in the Bowen Basin (more than 38,000 people) work in the mining, construction and/or manufacturing industries, and 80% of these work full time. This is much higher than the Queensland average of only 74% full time. Around one in seven workers (15%) in the Bowen Basin are fly in/ fly out (FIFO) and/or drive in/drive out (DIDO) workers, and this trend for non-resident workers is expected to increase (OESR, 2011).

Age group	As at 30 June					
	2006 ERP	2011	2016	2021	2026	2031
0–4	14,733	17,075	18,696	20,432	21,960	23,531
5–9	15,630	16,254	18,845	20,297	22,149	23,845
10–14	16,504	16,764	17,494	20,108	21,615	23,573
15–19	14,871	16,314	16,458	17,125	19,678	21,192
20–24	14,080	15,895	17,530	17,704	18,630	21,369
25–29	13,221	16,747	18,601	19,906	20,478	21,792
30–34	14,305	15,423	19,140	20,772	22,186	23,088
35–39	14,827	16,305	17,508	21,088	22,848	24,380
40–44	15,817	16,299	17,946	19,131	22,803	24,682
45–49	15,550	16,409	17,268	18,813	20,115	23,805
50–54	13,623	15,302	16,494	17,412	18,936	20,304
55–59	11,894	13,018	14,920	16,093	17,118	18,622
60–64	9,184	11,078	12,605	14,421	15,661	16,766
65–69	7,090	8,464	10,781	12,221	14,049	15,356
70–74	5,428	6,443	8,119	10,393	11,834	13,683
75–79	4,330	4,717	5,916	7,545	9,766	11,205
80–84	2,807	3,507	4,007	5,109	6,632	8,696
85+	2,271	3,161	4,318	5,361	6,859	9,051
Total	206,166	229,173	256,644	283,931	313,314	344,938

Table 2. Projected population by age group, medium series projections, Fitzroy Statistical Division, 2006 to 2031. ERP = Estimated resident population. (Source: Queensland Treasury, Office of Economic and Statistical Research[2])

[1] These are the most recently available data; 2011 Census datacubes are not yet published.
[2] Available online at http://www.oesr.qld.gov.au/regions/fitzroy/tables/proj-pop-series-age-group-sd-qld/proj-pop-series-age-group-fitz-sd.php.

Also based on 2006 Census data, over 15% of employed Indigenous males in the Bowen Basin work in the construction sector, with a similar number working in manufacturing; mining accounts for another 11% of the workforce. Most of the Indigenous workforce of the Bowen Basin receives lower weekly gross incomes than do the remainder of the population.

In 2009, tradespeople and labourers together represented 29.1% of the wage and salary earners by occupation, with production and transport workers representing a further 11.4% (ABS, 2010). This is relevant in an environmental health sense because data from the ABS has shown that the 'the types of risks to which people are exposed in the workplace vary considerably according to the type of job they do and the industry in which they work' (ABS, 2011, p. 3). For example, in 2009–10, the National Health Survey reported that the highest rates of injuries were found among labourers (88 per 1,000), machinery operators and drivers (86 per 1,000), and Technicians and Trades Workers (78 per 1,000); meanwhile, much lower injury rates are found in professionals and managers (42 and 45 per 1,000, respectively) (ABS, 2011). For this reason, encouraging the development of a cleantech workforce – one that is strongly centred on new knowledge creation through sophisticated research and trialling, may suggest that the region could experience a lower overall rate of work-related injuries. Similar trends are also evident for workplace fatalities. Furthermore, a move away from resource-based enterprises may also assist in reducing injuries: national data indicate that the agriculture, forestry and fishing sector had amongst the highest rates of workplace injuries (some 77 injuries per 1,000)(ABS, 2011). The agricultural, fisheries and forestries sectors also suffered the highest fatality rate in 2009-10, followed by mining and construction.

4.5 Key health issues

4.5.1 Population health statistics

Data from the Social Health Atlas of Australia indicate that Fitzroy statistical division generally has poor population health statistics when values are compared with the state and national averages (Table 3). In particular, residents of Fitzroy statistical division suffer higher risk of respiratory system disease, and report high levels of physical inactivity.

4.5.2 Community health concerns

Within the area managed by the Central Queensland Rural Division of General Practice[3], the three major causes of premature mortality are lung cancer, circulatory system diseases, and injuries and poisonings, despite rates of both these being lower than the averages for country Queensland and Australia (PHIDU, 2005a). However, rates of physical inactivity (15+ years) are much higher in the Division (377.4 per 1,000 people) than the State and national averages, as are people with high health risks due to alcohol consumption (64.3 per 1,000 people)(PHIDU, 2005a). Some residents of also have psychological distress levels more than 5% above the Australian average (PHIDU, 2005a).

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[3] The CQRDGP services nearly 66,000 people living in the region bounded by Moranbah in the north, Theodore in the south and west to the Gemfields, a total of 163,919 km^2.

Average rate per 1,000			
2007-08/synthetic predictions			
Type 2 diabetes	3.6	3.5	3.4
High cholesterol	5.6	5.5	5.6
Males with mental/behavioural problems	10.0	10.4	10.1
Females with mental/behavioural problems	11.9	12.0	11.8
Circulatory system diseases	16.5	16.0	16.0
Respiratory system diseases	24.9	26.0	26.6
Asthma	11.7	11.4	9.7
Chronic obstructive pulmonary disease	2.5	2.4	2.3
Physical inactivity (persons 15 years and over)	38.4	36.9	34.3
Overweight males (persons 18 years and over)	36.8	36.2	36.0
Obese males (persons 18 years and over)	21.7	20.9	19.6
Overweight females (persons 18 years and over)	23.4	23.1	22.7
Obese females (persons 18 years and over)	18.3	17.1	16.4
Average annual rate per 100,000			
Population deaths, (15-64 years), 2003 to 2007			
Deaths from cancer	75.4	74.6	74.9
Deaths from circulatory system diseases	35.3	34.4	35.1
Deaths from respiratory system diseases	8.8	7.4	7.4

Table 3. Summary of selected health statistics in Central Queensland (Fitzroy Statistical Division). Source: adapted from PHIDU (2010). Shaded cells indicate where the Central Queensland region performs poorly compared with the state and/or national averages

For the Capricornia Division of General Practice[4], the population is characterized by a slightly higher proportion of children and young people, and of aged adults (65+ years) in the Rockhampton area; the coastal centre of Gladstone is instead populated by a higher proportion of young adults (35-44 years), more males than females, and a lower proportion of aged adults (65+ years) than the Queensland averages (PHCRIS, 2008). In addition, the Indigenous population of Rockhampton (the 'regional capital') is higher than the national average, and that township also has a greater proportion of people with socioeconomic disadvantage. Lung cancer is by far the leading cause of premature death (before age 75) in the CDGP, at 108.8 per 1,000 people, followed by circulatory disease and injuries and poisonings (PHIDU, 2005c).

Within the broader Bowen Basin area, many subregional areas have a higher proportion of middle aged adults, and sometimes of aged adults. According to Harper *et al.* (2004), the major causes of death and illness in these groups are chronic obstructive pulmonary disease, coronary heart disease, stroke, depression, suicide and self-inflicted injury, diabetes and lung cancer (as reported in Harper *et al.*'s Health Determinants Queensland 2004). The key pressures impacting on the health of the general population in both Central Queensland and Capricornia general practice divisions include harmful alcohol consumption, illicit drug use (Gladstone only), smoking, obesity, diabetes and mental health (including suicide), along with

[4] The Capricornia Division represents over 144 GPs practising in approximately 43 general practices in the Rockhampton, Capricorn Coast and Gladstone areas.

poor nutrition, physical inactivity, high blood pressure and poor vaccination rates (PHCRIS, 2008). Skin cancer detection and treatment is also a key issue given the geographic location of the region and sun exposure, and, for the Capricornia region particularly, rates of cervical cancer screening and asthma management have been raised as key issues (PHCRIS, 2008).

A recent study by Greer et al. (2010) examined community perceptions of the health effects of large industry operating in the Gladstone region. Industrial emissions, air quality and the possible associated human health risks have been a topic of ongoing concern in Gladstone, despite laboratory testing indicated that industry emissions are below levels that are harmful for human health. The report by Greer et al. noted that residents had the highest levels of concern about dust and air quality impacts, including coal dust from the rail and port facilities and odours and caustic vapours from the alumina refinery. Other high-ranking emissions included chemicals, water pollution, fumes, and land pollution.

4.5.3 Industrial and occupational health

In recent years, Central Queensland has had a number of reported health problems that are linked with existing industries. Firstly, in general terms, the key industry sectors upon which the Central Queensland economy is built tend to be those that have high reported rates of occupational hazards. For example, construction, manufacturing and agriculture each feature prominently in the CQ region, and these have consistently recorded the highest rates of workers' compensation claims at the national level (Fig. 5). Interestingly, the coal sector is an industry that often receives strong focus on safety outcomes. However, at the national level, data for lost time injury rates show that the performance of the sector has been steadily increasing in the past decade (Figure 6).

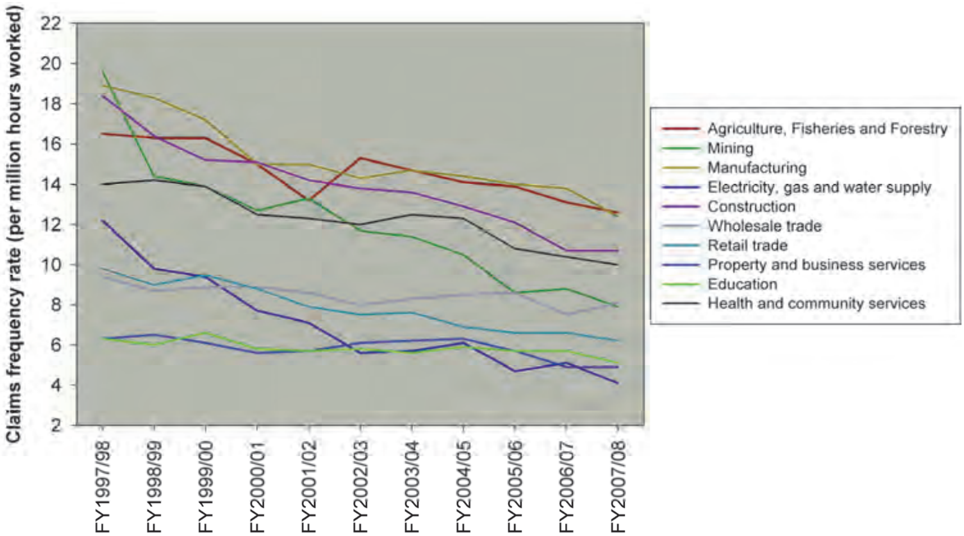

Fig. 5. Frequency Rate (per million hrs worked) of worker's compensation claims for 10 industry sectors relevant to Central Queensland. Data are national values sourced from Safe Work Australia. FY = financial year.

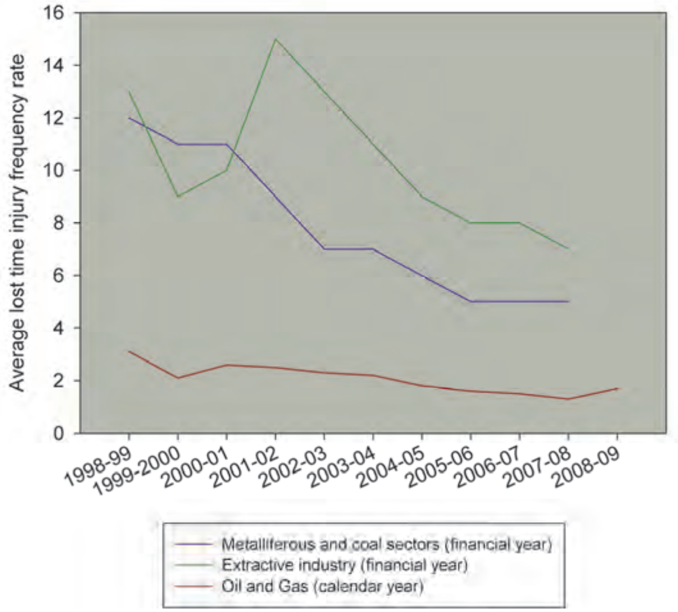

Fig. 6. Average lost time injury frequencies rates for metalliferous, coal, extractive industry and oil and gas sectors. Source: adapted from ABS Category 8417.0 Mining Indicators, Australia, December 2009.

Recent reports have also highlighted some specific problems with key industries. For example, both the mining industry, and the construction, electricity, gas and water industries show a high tendency to have workers that are overweight or obese, with 76% and more than 60% of mining workers in this classification, respectively (ABS 2005).

Secondly, the aluminium industry (both refining and smelting) has been recognised as the most significant contributor to air pollutants in the Gladstone region. According to the National Pollutant Inventory, in 2009-2010 basic non-ferrous metal manufacturing contributed to over 96% of the total 35,365 tonnes of reported carbon monoxide emissions. The industry was also responsible for over 89% of the total 654 tonnes of $PM_{2.5}$, 41% of 42,502t of SO_2 and 22% of a reported 47,815t of oxides of nitrogen (Department of Sustainability, Environment, Water, Population and Communities, 2011). Each of these pollutants is known to cause or contribute to health effects, including respiratory and cardiovascular complaints.

4.6 Establishing a cleantech CQ hub[5]

Simply put, the 'Cleantech CQ' concept refers to a deliberate and strategic effort to attract, develop and/or adopt a concentration of clean technology industries and practices within

[5] This material draws heavily on Susan Kinnear and Ian Ogden, 2010, 'Beyond Carbon: a case study of Cleantech and innovation for sustainable regional development in Central Queensland, *Proceedings of the Social and Economic Growth for Regional Australia (SEGRA) 13th National Conference*, 19-21 October 2010, Townsville, QLD.

the central Queensland region. This might include some or all of retrofitting or redesigning existing industry (including introducing new products and technologies), and/or the establishment of entirely new industries based on better resource efficiencies or resource re-use. Ideally, a culture of environmental awareness and appreciation would develop, and the regional communities would look toward capacity-building in clean technology wherever possible. For example, this might include dedicated cleantech skilling and training programs, as well as new knowledge creation for application in regional industries and/or for export potential. The latter might include the design and creation of novel environmental monitoring devices.

5. The Central Queensland advantage

Central Queensland (CQ) has a number of features that make it particularly attractive and competitive as a region in which clean technology might be developed as a key sector. For example, Central Queensland has exceptionally high demand for clean technology, which results from a combination of pressures including:

- the number of existing and planned heavy industries operating in the region, with all of these under pressure to perform sustainably whilst maintaining profits;
- the high carbon-intensity of the region: one report predicted that Fitzroy Division would bear costs twice as high as any other location in Queensland if carbon trading was introduced[6] (KPMG 2009);
- the location of the region being directly upstream of the Great Barrier Reef, meaning that regional industries are under considerable pressure to improve the water quality flowing through the Fitzroy catchment and onto the GBR lagoon, whilst not sacrificing productivity;
- the pressures of regional climate change (as already described above);
- the need for small businesses to reduce operating costs in order to compete with the mining industry as well as in the global supply chain; and
- since CQ straddles Queensland, cleantech development in the regional transport sector is particularly valuable because of the high costs of transporting goods throughout the region, and into the region from other areas.

Central Queensland also boasts a profile of key physical resources and characteristics that are relevant to developing a Cleantech industry. For example, these include:

- good land availability (including rehabilitated industrial lands and lands accessible to ports and other transport infrastructure);
- a bountiful regional water supply; and
- a number of existing coal-fired power generators, well-developed transmission networks; and a diversity of natural energy resources (including solar, gas fields, and waste products suitable for adaptation into biofuels or other industrial feedstocks).

Central Queensland has a diverse economy built on a wide array of sectors including mining, agriculture, manufacturing and processing (e.g., two significant meat processing

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[6] Please note that these data were prepared based on the first iteration of the Emissions Trading Scheme, which was later defeated in the Senate.

plants), education, tourism and a regional transport hub: each of these can contribute to the development of a Cleantech industry. Indeed, one of the key strengths of Central Queensland as a Cleantech destination is because the region is not solely linked to the resources sector: CQ also has a range of secondary industries (tourism, transport, SMEs) in which cleantech could be adopted.

A cleantech CQ hub would achieve a natural fit with a number of existing regional planning mechanisms and agendas. For example, the CQ Strategy for Sustainability already has key themes of responding to regional climate change; issues regarding carbon emissions, business resilience and competitiveness; social targets such as community awareness and adoption; and regional coordination. Furthermore, in many respects, establishing such a Hub would not require a huge diversion from existing plans. For example, there are already a number of non-renewable green energy projects planned for Central Queensland, particularly in the area of coal-seam gas generation (Kinnear et al., 2010) (Figure 7).

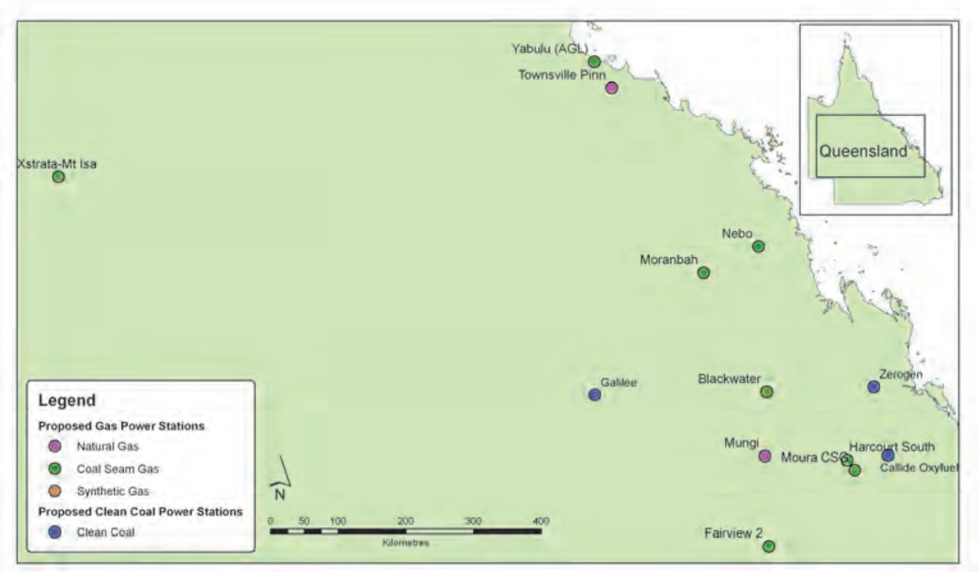

Fig. 7. Planned or proposed clean-coal or natural-gas fired energy generation sites in Central Queensland.

5.1 Potential environmental health benefits from a cleantech CQ hub

Identifying and quantifying the environmental health benefits that may be afforded by a cleantech CQ hub first requires an understanding of the changed regional profile under two future scenarios: one based on a continuation of business as usual (i.e., ongoing expansion of the heavy industry that is already in the region) and the other being the deliberate development of a cleantech CQ hub. This kind of scenario-building can be used in order to conceptualise what environmental health outcomes might be realised across the region, including the comparative health risks and benefits of 'conventional' versus 'cleantech' industry approaches. For CQ, generally speaking, the 'business as usual' scenario is likely to be associated with the continuation of CQ as a resource-based economy (i.e., trading in the mining boom): this would involve strong activity in coal extraction and coal-fired energy production, minerals processing and manufacturing industries, and conventional agriculture. In contrast, a 'cleantech CQ' future would witness the development of the region as an innovative, environmentally-conscious and knowledge-based economy (trading in the "the mind boom"): here, key industries would involve growth in renewable energy, education and skilling, eco-tourism, environmental monitoring and management, new generation agriculture, climate adaptation and mitigation.

Clearly, in the absence of specific data and predictions about the nature and number of new industries, and/or the adaptations that might be embraced by existing industries under a 'cleantech CQ hub', it is very difficult to forecast the specific environmental health benefits that might be associated with this initiative. However, considering the geographic, demographic and socio-economic profile of CQ, there are a number of generic environmental health benefits that could be expected, and some of these are described in further detail below.

5.1.1 Direct regional impacts

Establishing a 'Cleantech CQ' hub could be linked with a number of specific and direct environmental health benefits in the region. For example, the hub may foster a regional culture that incentivizes existing polluting industries to perform more cleanly – thus reducing aerosols such as coal dust, NOx, SOx, and VOCs. For example, the 'Clean and Healthy Air for Gladstone' project was largely initiated due to concerns voiced in the community. Of note here is that the Yarwun alumina refinery in Central Queensland will more than double its production capacity in 2012. While the emissions from this site can be expected to increase accordingly, advances in technology ('cleantech') should ensure that this is not at a proportionate scale. Furthermore, one of the major sources of pollutants in the alumina industry is linked with the intensive electricity demand by the refining process. Traditionally, this electricity has been provided by coal-fired plants. However, the Yarwun 2 refinery is powered by a gas-fired cogeneration plant to produce steam and power for the operation, emitting significantly less CO_2 and particulate matter than a comparable coal-fired plant (Bechtel 2011).

More data are needed on the benefits that might flow from the ability of a cleantech hub to help the regional community mitigate and adapt to climate change. This will be important information given that regional predictions for CQ point to warmer and drier temperatures, both of which pose health issues.

5.1.2 Indirect regional impacts

In terms of indirect impacts, the cleantech hub can be used as a driver for economic prosperity, particularly in the western subregional areas of central Queensland, which are currently underperforming in terms of economic development. Where a regional cleantech hub contributes to overall increase in employment, as well as to better wage conditions, then general improvements in public health could be expected, because lower socio-economic status has been shown to be linked with poor health outcomes. Thus, as fewer regional residents are unemployed and a greater proportion of the region receive higher wages, an improvement in health indicators should follow. This would be especially true if project components could be developed specifically within the Woorabinda Aboriginal Shire Council area, where health and income statistics are extremely poor. The hub would also provide for economic diversity, therefore reducing dependency on the coal mining industry – the latter being associated with poor liveability and poor health outcomes in terms of fatigue, depression, heart disease and domestic violence.

5.1.3 Impacts at other scales

The environmental health benefits of a cleantech hub in CQ will manifest at regional, national and global scales. As an example, changed climatic conditions have been predicted to impact upon agricultural production across Australia- one example being an increased potential for mycotoxin contamination of grains intended for human and animal consumption (Bricknell, 2008). The reduction in greenhouse gas emissions associated with cleantech hubs have the potential to contribute to a reduction or slowing of this effect, depending on the scale and extent of their operations.

A present, the nature of such impacts is speculative, as the ability of practitioners and decision-makers to clearly identify and quantify them is extremely limited. Furthermore, the relative importance of these will decrease in that order: whilst it is possible that the regional health impacts may be specific and (in time) measurable, any contribution to national and international health parameters will always be vague and very limited, given the scale and complexity of natural, industrial and human systems at those levels.

6. Future directions for cleantech and environmental health

6.1 Research and knowledge gaps

Clean technology development has a potentially significant role in optimising both direct and indirect environmental health outcomes. Clearly, at the regional level, the nature of any public health risks or benefits of cleantech will be dependent on:

- the type of clean technologies adopted
- the type of existing industry they replace (if any); and
- the regional profile in terms of
  - climate (including expected climate change);
  - population demographics (especially in terms of proportions of very young, very old, and indigenous subgroups, and how these are expected to change in coming decades); and
  - the pre-existing and/or prevalent health conditions within the region (particularly respiratory complaints).

However, the knowledge and data in this space is very limited and needs to grow: there are a paucity of studies on the health impacts of existing industry, as well as the health benefits of newer or alternative technologies. Consequently, specific figures on the health conditions that are reduced or avoided through the regionally wide adoption of cleaner technologies (such as in a regional 'hub' approach) are extremely difficult to calculate.

The environmental health benefits of cleantechnology development need to be included as part of the overall business case and argument for cleantech hubs, particularly in rural-regional areas of Australia where poorer health outcomes may be evident. However, detailed datasets and modelling will be required in order to gain a clear picture of the risks and benefits of the development of cleantech industries at the regional-level. Fortunately, the increasing focus on carbon and other greenhouse gas emissions is accelerating research in this space. For example, work on the use of geographic information systems (GIS) to collect and analyse data on the health impacts of vehicle emissions, including the role of key parameters such as population, baseline mortality and background air quality, is already underway (ICCT, 2011).

Future research in this space should be centred on answering questions such as:

- what is known about the links between economic development/resource use and environmental health outcomes in the regional areas of Australia?
- what are the key issues that need to be addressed for better regional environmental health outcomes, and how might these be actioned?

Furthermore, a greater focus needs to be dedicated to our understanding of the crossovers between ecological and environmental health, and how these could be better pursued simultaneously. There is also a need to develop (or adapt existing) methodologies to quantify the environmental health benefits of clean technology development and adoption. For example, a simple method might be to compare lost time injury rates of conventional coal-fired power stations with those of renewable energy generators, thus describing the actual value of the occupational health outcomes. The US EPA (2010) has pioneered a staged approach to estimating the environmental and health benefits of clean energy options, comprising a four-step process as detailed below:

1. Develop and project a baseline emissions profile (compiling air pollutants and/or greenhouse gases from available sources into an inventory and develop a forecast);
2. Quantify air and greenhouse gas emission reductions from clean energy measures (noting the operating characteristics of the clean energy resources, and profiling the impacts when they occur);
3. Quantify the air quality impacts by using air pollutant data in an air quality model; and
4. Quantify the human health (and related economic effects) through a combination of air quality changes data, epidemiological and population information; and economic values of avoided health effects (US EPA, 2010, p. 99).

However, this kind of study remains very data-intensive, which is a discouragement to local planning authorities.

6.2 Policy and planning implications

There are a number of international examples that highlight the policy implications of the linkages between regional development, cleantech growth and public environmental health outcomes. For example, Mead (2011) recently commented on the positive health outcomes that would result from the Chinese policy shift towards clean energy technology, renewable energy targets and national fuel efficiency standards; together with more stringent enforcement of existing laws in pollution abatement, resource conservation and ecological management. Mead (2011) noted that one of the key drivers for China’s investment in these areas was the high premature death rates linked with outdoor and indoor pollution from energy generation: this is a clear example of environmental health concerns being a key driver for policy, despite the fact that the specific health outcomes (benefits) that may result from a cleaner Chinese energy production system have not yet been described.

In the Australian context, some industries are already required to report annually on various statistics related to employee safety (e.g. lost time injury rates), but not on public health risks associated with their operations. On the other hand, since 2007, many companies have been mandated to participate in the National Greenhouse and Energy Reporting System (NGERS), which reports greenhouse gas emissions. Proposals for significant new projects are required to undertake detailed environmental and social impact assessment processes, including information on the possible health implications (noise, odours, air and water pollution) of their operations. However, this process could be strengthened by asking for an identification of viable fuel and process alternatives, together with a consideration of the differing public health benefits that would be associated with each.

Establishing new planning strategies for the development of cleantech hubs may help to bring forward new ways of scanning the multiple and cumulative impacts of key industries operating in a region, and encourage coordination in the way these risks are measured and managed. Consideration also needs to be given to the planning and environmental health implications of 'cleantech hubs' and how these should be recognised and managed in the pre-developmental phase. For example, in Australia, it has recently been acknowledged that the National Wind Farm Development Guidelines should be redrafted to include provisions for adverse health effects (CARC, 2001). Furthermore, following a study of future air pollution emissions in the San Joaquin Valley region of central California, Hixson et al. (2010, p. 11) recommended that 'regional planning agencies should develop thresholds of population-weighted primary emissions exposure to guide the development of growth plans'. Finally, clean technology industries should also be developed with a consideration of how environmental health (and indeed, other socioeconomic) benefits can be maximised, such as deliberate attraction of an Indigenous workforce, strategic placement of operational sites, and optimal use of regional resource bases (including waste).

7. Conclusions

Developing a 'cleantech' sector is an excellent way to advance the sustainable regional development agenda in Australia. The development of cleantech hubs in regional settings have the potential to solve not only environmental issues, but also environmental health issues, and in turn, regional development issues (e.g., relieving pressure on regional health and services infrastructure in the long-term). In its widest sense, cleantech urges a shift in economic development thinking, from one of growth based on natural resource extraction and/or utilization, to instead the building of knowledge- and skills-based economies that do not require drawdown on, or damage to, natural assets. In this sense, public health gains are achieved by default, as the health complaints linked with conventional mining, energy production or other resource development and transport systems are avoided. Unfortunately, there are few specific examples of the human health outcomes that are linked with clean technology. A review of the existing works suggests that in terms of occupational health, the key benefits of cleantech are likely to be predominantly linked with a decrease in workplace risk factors related to cancers (carcinogenic exposures), respiratory disease (air emissions), and accidents. Meanwhile, in terms of wider public environmental health, the role of cleantech in decreasing air emissions burden is likely to be significant, especially where this reduces hazardous emissions associated with heavy industrial operations and coal-fired electricity generation.

A cleantech CQ hub is one way that Central Queensland can simultaneously address goals of sustainability, productivity, innovation, regional competitiveness and strengthened communities. The CQ region is uniquely placed to resource and support a vibrant cleantech sector, but to date, the value of this development has only ever been considered from an economic and environmental (ecological) perspective. This case study has helped to highlight the linkages between ecological and human health effects, as well as identify examples of the likely environmental health benefits (both employee and public) that might be expected to occur under the development of a regional cleantech hub. However, far more studies are required if a strong case for clean technology is ever to be based on its environmental health advantages.

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