

Co-benefits of large-scale renewables in remote Australia: energy futures and climate change

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Abstract. Desert/remote Australia is blessed with abundant natural energy resources from solar, geothermal and other renewable sources. If these were harnessed and connected appropriately desert/remote Australia could be not only energy self-sufficient but a net exporter. Generation of abundant, clean energy can also attract energy-intensive industries and provide local income and employment. Such co-benefits should be included in any cost-benefit analysis.

Regardless of renewable energy's contribution to reducing climate change, the world is already committed to global warming and associated climate changes. Desert/remote Australia will thus inevitably get warmer, with implications for health, energy demand and other issues, and may be subject to increased extremes such as flooding, longer dry spells, more severe storms and coastal inundation.

In addition, the prospect of world demand for oil from conventional sources exceeding supply will likely lead to oil shortages, higher oil prices, and additional incentives to provide alternative energy supplies. The region is heavily reliant on diesel generators and fossil fuel-powered motor vehicles and airplanes for transport for within-region mobility, the importation of goods, the tourism industry and emergency medical services.

Without adaptation, climate change and peak oil will make living in desert/remote Australia less attractive, resulting in increased difficulty of attracting and retaining skilled workers, which would constrain development.

This paper focuses on the climate and energy-related impacts and potential responses. These are both a challenge and an opportunity. They could provide additional employment and income, thus helping remote communities to participate in the clean energy economy of the future and thus overcome some serious social problems. The paper attempts to review current knowledge and provoke debate on relevant investment strategies, and it teases out the questions in need of further research.

Additional keywords: electrical grid, employment, income, Indigenous communities, peak oil, remote communities.

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Climate change impacts on desert/remote Australia

Climate change and risk

Climate change projections necessarily depend on assumptions regarding future emissions of greenhouse gases, and have many uncertainties due to the highly complex nature of the climate system. The potential impacts regionally and globally may be very serious, requiring important changes in economic and technological systems. However, the uncertainties about future climate have led some people, whose commercial and/or ideological interests appear to be threatened or who are otherwise in denial, to focus on the least possible impacts and to deny that more serious impacts are possible or even likely. Such people argue that they are merely applying normal scepticism to the conclusions of climate change scientists. This usually pits supposed 'common sense arguments' for denial against relevant professional expertise, analogous to a patient with the early symptoms of a disease rejecting unwelcome advice from a medical specialist.

The strong consensus of climate scientists is that the well-recognised uncertainties contain a significant risk of serious impacts that ought to be taken into account in planning and policy measures. Risk is defined as the probability multiplied by the magnitude of any impact. Future climate change and its possible impacts and opportunities are matters for risk management policies such as preventive measures and insurance. Even a small probability of a highly damaging outcome requires precautionary action rather than inaction on a 'wait and see' basis. Waiting until after it has burned down to insure our house against fire would be a bit late.

It is sensible, therefore, for the public and decision makers to take seriously the well-refereed conclusions of thousands of scientists summarised in the various reports of the Intergovernmental Panel on Climate Change (IPCC 2007a, 2007b) and supported by many reports and statements from National Academies of Science and professional scientific bodies (see summary in Pew Center 2009 and Pittock 2009a).

In Australia, the Bureau of Meteorology, CSIRO, the Australian Academy of Science (AAS 2010a) and numerous university scientists and institutions have issued numerous relevant reports and statements including CSIRO (2011a), CSIRO and Bureau of Meteorology (2007, 2010), Green *et al.* (2009) and Pittock (2003). The present paper takes these reports into account in making the following summary statements regarding climate changes and impacts likely in desert and other remote regions of Australia.

Observed and projected climate changes

The CSIRO–Australian Bureau of Meteorology statement (2010) documents a warming trend over the whole of Australia from 1960 to 2009 of up to 0.6°C per decade in parts of inland Australia, with lesser warmings in many coastal areas, including the Kimberley region in the north-west where rainfall has increased. Despite, or because of large year-to-year variability, there has been no significant trend in rainfall in central Australia, but there have been decreases in southern and eastern regions.

Recent record extreme events in late 2010 and early 2011, especially in eastern Australia, have been associated with an extreme La Niña event and associated tropical cyclones (TC). These were likely exacerbated by record high sea surface temperatures, which increase atmospheric moisture content. This has yet to be fully documented, but is consistent with several papers written by CSIRO scientists in the 1990s (e.g. Gordon *et al.* 1992; Fowler and Hennessy 1995; Hennessy *et al.* 1997; IPCC 2007a).

Globally, average sea level has risen by some 20 cm from 1870 to 2007. Locally, from 1993 to 2009 sea level has risen by 1.5–3 mm per year in the southern and eastern coastal regions, and by 7–10 mm per year in the northern and western coastal regions. Regional differences are largely due to variations in ocean currents and atmospheric pressures.

The global atmospheric carbon dioxide concentration in 2011 was about 392 parts per million (NOAA 2011), which is much higher than the natural range of 170–300 parts per million that existed for at least the last 800 000 years. Besides driving global warming, this increase is causing increases in acidity of the oceans, as has already been observed (Hoegh-Guldberg *et al.* 2007).

The CSIRO–Australian Bureau of Meteorology statement (2010) concludes that Australia will become hotter in coming decades, and that much of southern and eastern Australia will become drier on average. It also restates the IPCC (2007a) conclusion that there is greater than 90% certainty that increases in greenhouse gases have caused most of the observed global warming since the mid 19th century, and that it is extremely unlikely that the global warming could be explained by natural causes such as variations in solar output (see also Pittock 2009b).

More detail of projected climate changes in regional Australia can be found in Suppiah *et al.* (2007) and in Chapter 11 of the IPCC Working Group II report (IPCC 2007b). These suggest that in central Australia warmings are likely to be in the range of 0.5–4.0°C by 2050 and 0.8–8.0°C by 2080. The wide range is partly due to differences between different climate model estimates and partly from uncertainty as to future levels of greenhouse gases. Without marked reductions in the rate of

increase in greenhouse gas emissions, future warmings are likely to be in the upper half of the stated range. Warmings are projected to be less near the coast.

The Australian reports are not conclusive about future rainfall changes in northern Australia, with climate models predicting a wide range of possible changes centred around no change, despite observed increases (CSIRO and Australian Bureau of Meteorology 2007; Suppiah *et al.* 2007). Nevertheless, the risk study by Green *et al.* (2009) does suggest an increase in wet season rainfall in most of tropical Australia (p. 30).

Moreover, simple first principles suggest that monsoon circulations are primarily driven by land-sea temperature differences between continents and their surrounding oceans. Greater warming over land leads to increased updrafts, which would increase the release of latent heat of condensation, driving more intense convection. This suggests that the Australian monsoon should be intensifying with global warming, as ocean temperatures tend to lag behind continental temperatures. This is complicated by the effects of atmospheric pollution of the lower atmosphere (particulate pollution from human activity). To the north of Australia this arises largely from industrial pollution in Southeast Asia, which has a regional cooling effect on the waters north of Australia. This suggests a further strengthening of the Australian monsoon (Rotstayn *et al.* 2007), but increased smoke cover over northern Australia due to possible increased bushfires could work against a stronger monsoon. However, the smoke effect might be expected to decrease once the monsoon has set in, doused the fires and washed out the smoke.

The recent Australian reports do not highlight increases in rainfall intensity, but the IPCC (2007a) report projects increased rainfall intensity in general, even in some areas where average rainfall decreases. Earlier papers (e.g. Gordon *et al.* 1992; Fowler and Hennessy 1995; Hennessy *et al.* 1997) documented this as a result projected for Australia in several climate models. It is essentially due to the capacity of warmer air to hold more moisture, so that more intense rainfall is likely, especially in convective storms where additional latent heat of condensation amplifies the convection. This especially applies to tropical cyclones (TC), with an expectation of a greater number of more intense TC, even though the total number of TC may not increase.

Projected impacts

Projected impacts are discussed in some detail in the report by Green *et al.* (2009), but this is confined to Aboriginal and Torres Strait Islander communities in the tropical north of Australia, and thus does not consider many of the more inland desert region communities. Chapter 11 of the IPCC Working Group II report (IPCC 2007b) covers impacts in Australia and New Zealand in general, but with little detail on many remote areas.

The most obvious projected impacts are marked increases in the number of extremely hot days in inland Australia, and decreases in the frequency of extremely cold days. This will seriously impact on comfort levels in buildings and especially increase the need for cooling in the warm season, and thus on energy and water demand for cooling systems. It may also contribute to greater wildfire risk, especially in the dry season and where rainfall does not increase, although fire spread and intensity will depend on the density of vegetation, which may change with

the climate. Impacts on animals and humans outdoors will also be significant, with increases in demand for water.

Increases in tropical cyclone severity will have serious impacts on coastal communities, due to stronger winds and also larger storm surges on top of long-term sea-level rise (CSIRO 2011b). Communities further inland will also be affected by strong winds and extreme rainfall events associated with tropical depressions resulting from cyclones moving inland. This is likely to increase the severity of riverine and flash flooding.

The Green *et al.* (2009) report considers the effects on Aboriginal and Torres Strait Islander communities in the tropical north, especially on biodiversity, health, infrastructure, education and livelihood opportunities. It is worth quoting from the resulting summary of impacts of global warming and possible strategies for coping with it, as these apply generally to remote Aboriginal and Torres Strait Islander communities:

- Climate change will impact the natural environment of the north both directly and indirectly, with major flow-on implications for remote communities dependent on natural resources. These impacts are generally poorly understood although it is clear that the role of people in the landscape to manage these impacts will be crucial (discussed in Chapter 3).
- Climate change is likely to exacerbate existing, and create new, health risks for Indigenous people. Proactive adaptation to these risks would lead to no-regrets improvements to health. These strategies should be identified and acted on as soon as possible (discussed in Chapter 4).
- Both transport and communications infrastructure in many areas of the study region are extremely limited. Climate change will cause disruption to the infrastructure that does exist, particularly in coastal regions. Improving key access points, raising new and existing building standards for cyclone-proofing and enhancing the resilience of local energy provision and maintenance systems are critical investments (discussed in Chapter 5).
- Education has an important role to play in preparing northern communities for climate change. However, amendments to current curricula are required to enhance the capacity of communities to adapt and build resilience to climate change impacts. The role of Indigenous knowledge in strengthening cultural resilience must also be specifically recognised in any education program (discussed in Chapter 6).
- Some economic opportunities may arise from the need to better manage, and in some cases restore, ecosystems for biodiversity conservation and for carbon dioxide mitigation and sequestration activities. Opportunities and livelihood options related to this issue need to be better understood (discussed in Chapter 7).

While the Green *et al.* (2009) report is focussed on Aboriginal and Torres Strait Islander communities, its conclusions are in general applicable to non-Indigenous communities as well, and must be seen as essential considerations in town planning and development.

‘Peak Oil’ and energy prospects in the 21st century

The idea that oil production would reach a peak and then decline was first put forward by M. King Hubbert in 1956 (see Deffeyes 2001). He predicted that US oil production would peak in the early

1970s, which it did. Repeated oil shortages in recent decades have caused rapid, although rather spasmodic, rises in oil prices, and it is now clearly evident that oil extraction is becoming more difficult. Shallow oil deposits are becoming depleted and deeper oil wells, especially offshore, are now necessary. These deep oil wells are more costly and open to damaging spills such as that in the Gulf of Mexico in 2010. Resort is also being made to exploitation of shale oil and tar sands, both of which present environmental problems, especially higher greenhouse gas emissions, and are more expensive as they require large amounts of energy to extract the oil.

The situation internationally was put into stark relief by the US ambassador to Australia recently (Bleich 2010) who wrote:

Fossil fuels are indisputably finite – unlike wind, solar, biofuels and other renewable sources. They will run out one day, and our economies will collapse with them unless there is an alternative. In short, our reliance on fossil fuels threatens not just our environment, but our economy, our national security, and every aspect of our future.

The temporary halt to oil price rises during the global economic crisis of the late 2000s may well resume as soon as there is an economic recovery that lifts demand (e.g. ASPO 2010; Global Energy Systems 2010; and references in Pittock 2009a, pp. 208–9). This will have severe economic repercussions, especially for sectors dependent on oil in the form of petrol or diesel. This includes most of the remote areas of Australia where transport, machinery operation and even electricity generation is highly dependent on these commodities. The exact timing of such a crisis is highly debated but could be within a decade or so, unless natural gas or gas from unconventional sources is widely used as a transition fuel.

There will be serious impacts on day-to-day living in remote Australia, and an urgent need for alternative sources of electricity and fuel. Railways, cars, trucks and machinery will need to run on biodiesel or other alternative fuels such as renewably generated electricity or hydrogen. Even such alternatives as liquid ammonia, used during World War II, may be needed, and may prove to be economic (Bruce *et al.* 2008; AFN 2010; NH3 2010). Ammonia can be generated from hydrogen and nitrogen, with the hydrogen itself coming from the electrolysis of water by electricity from renewable sources, reacting with atmospheric nitrogen. Biodiesel is the most popular suggested alternative to oil, but it requires water to grow biomass and energy to harvest and collect the biomass. Even air transport, vital to many in the outback, especially in emergencies, may need to run on alternative fuel.

Possible responses to climate change and peak oil

Avoid damaging climate change through reduction of emissions. This is a global requirement and Australia will be obliged to play its part, both locally and via international agreements, motivated by likely local, regional and global impacts of global warming. The local response would include reduced reliance on fossil fuels and thus more reliance on renewable energy and energy efficiency. This need will be accentuated by the onset of ‘peak oil’, or at least by rising oil prices when demand picks up after the global financial crisis.

Thus biofuels or other renewable energy sources (as above) will be in demand for transport. Water availability may become a key issue, both for biofuel generation and for domestic and industrial cooling.

Proactively manage impacts. This includes planning for and investing in measures to cope with rising sea levels, greater warmth, more extreme flooding and wind storms, and possible health impacts. This will require massive efforts to modify and strengthen infrastructure to withstand extreme climatic conditions, especially heat, damaging winds, and coastal, riverine and flash floods. Appropriate zoning and design rules will be needed.

An essential element in better coping with the impacts of climate change is sustainable development, which increases society's ability to cope with stresses, damage and disasters (e.g. IPCC 2007b; chapter 20). This is crucial in the case of lesser developed communities or countries, which can ill afford to cope with adverse climatic events.

Seize opportunities. These especially include greater demand for renewable energy, including stationary electricity and transport fuels. Such opportunities will become increasingly attractive as the costs of fossil fuel energy increase, and renewable energy technology becomes cheaper. As renewable energy opportunities are abundant in remote Australia (Beyond Zero Emissions 2009; Seligman 2009; AAS 2010b; Climate Institute 2010; Climate Works Australia 2010; Department of Resources Energy and Tourism 2010), this provides a great opportunity for increased local employment and income (ACF and ACTU 2008, 2010; Hatfield-Dodds *et al.* 2008; and see below).

Linking remote Australian communities to the national electricity grid may provide other opportunities, not only in installing and maintaining the grid but eventually in possible export of energy and fuels to Asia via an under sea high voltage direct current (HVDC) cable link to Indonesia (Desertec-Australia 2010) or generation and export of hydrogen fuel.

An under sea link to Indonesia may seem extravagant, but the European Desertec Foundation proposals for supplying Europe from renewable energy in North Africa and the Middle East are beginning to be acted upon (TREC 2007; and updates at Desertec 2011) despite political instability in the region. This involves cable connections of the order of 500–1000 km in length, made economical by the very low transmission losses of HVDC cables. This is comparable to a link from, say, Darwin to Timor.

A study by PriceWaterhouseCoopers (2010) supports the idea of a Europe–North Africa power market with a unified intra- and inter-continental grid, while an International Energy Agency study identifies large renewable energy potential within Southeast Asia (IEA 2010; Ölz and Beerepoot 2010). What is economically possible in regard to export of Australian renewable energy to Southeast Asia remains to be thoroughly explored. Such development in Australia is probably decades away but should be considered in network design. Precedents exist in the existing Bass Strait cable (about 290 km) and the proposed Origin Energy (2010) link from Papua New Guinea to Townsville, which includes some 500 km of under sea cable.

Anticipate, plan and invest in other potential shifts in employment and income sources. These will include changing farming and forestry practices and opportunities as climate changes. Aspects of national resource management strategies,

such as in conservation of biodiversity and carbon sequestration will be increasingly important (e.g. see the Aboriginal Carbon Fund 2011; and the federal government's *Clean Energy Future Policy* 2011).

Wait, see and cope with any changes. For those who remain sceptical about the prospect of serious climate change impacts this may appear to be the best option. It necessarily includes a willingness to cope with and rebuild after any damaging impacts, or to retreat (i.e. migrate from untenable areas). It may be very costly and may quickly become an unacceptable option.

Renewable energy opportunities in remote Australia

Especially with its large areas of low-latitude arid land, Australia is blessed with the most solar energy of any country in the world, plus geothermal, wind, tidal, etc., especially in remote areas. This is well documented in several reviews including that of Chopra and Holgate (2005), Service (2005), Seligman (2009), Beyond Zero Emissions (2009), Climate Institute (2010) and Department of Resources Energy and Tourism (2010).

Solar energy is clearly most abundant in inland and desert Australia but also seasonally in more southern regions in summer and in more northern monsoonal regions in winter. Seasonal variations and east–west time zone differences of up to 3 h mean that a national electrical grid (if economically justified) can largely smooth out seasonal and daily demand cycles to provide effective baseload power. Solar thermal storage, pumped hydro (either from existing dams or from coastal cliff-top storages using sea water as discussed by Seligman 2009), use of geothermal energy, electric vehicle batteries or generation of hydrogen or other fuels can all add to the ability to satisfy demand in a timely fashion. Natural gas is already used to supply peak demand in some cases, but, while it is less emissions-intensive than other fossil fuels, it still has significant greenhouse gas emissions and will become increasingly unacceptable.

Glennon and Reeves (2010) discuss problems in the US with site approvals for large-scale solar projects. However, remote areas of Australia include huge areas that are suitable, with few competing interests. Location on Aboriginal lands may well be possible with active Aboriginal support.

The need for reduced greenhouse gas emissions provides a strong in-principle incentive for more renewables. This would be assisted economically by a price on carbon emissions, either through a carbon trading scheme or a direct tax, but can also be stimulated by start-up or other incentives. Renewable energy targets are one such mechanism, but it may well be that providing a suitably extended electrical grid and/or energy storage systems might encourage economies of scale that make renewables economically competitive within a decade or two. There is a need to model the economics of such schemes taking account of all the costs and benefits, including local employment, environmental and health benefits. Fossil fuel energy also has costs not usually considered, such as other environmental pollution, health hazards and numerous subsidies, tax concessions and infrastructure costs (Riedy 2007).

There is already wide interest in renewable energy developments, not only from environmental non-governmental organisations (NGO) but from business and government authorities. However, most have failed to recognise the co-

benefits to remote area communities, which if quantified could add to the economic case for such developments. A notable exception is the Centre for Appropriate Technology and the related Desert Knowledge Solar Centre in Alice Springs (contactable at www.dkasolarcentre.com.au), but these have largely focussed so far on small-scale renewable energy.

The Australian Energy Market Operator (AEMO) has studied the economics and design details of an extended electricity grid (AEMO 2009a) and in particular done a case study of an extension to Innamincka (AEMO 2009b) near the Cooper Basin geothermal development. These studies discuss the relative merits of high voltage AC versus DC transmission, and conclude that a mixture may be most appropriate, with DC most economical for long uninterrupted transmission lines or where easements may be constricted, or underground or under sea cabling is needed.

The AEMO (2009b) study estimates the cost of extending the grid to include the Cooper Basin at around AU\$2–5 billion, depending on the routes and capacity. Clearly the costs of easements would be reduced if they could be combined with easements for other purposes such as natural gas pipelines or the trunk lines for the National Broadband Network (NBN 2010), which by way of comparison has a total price tag of some AU\$43 billion.

To put these cost estimates in perspective, according to Paddy Manning in *The Age*, Melbourne, of 12 June 2010, ‘forecast spending on Australia’s electricity network over the next 5 years is the country’s biggest single-ticket infrastructure item, at an estimated \$47 billion.’ This includes high voltage transmission lines, spending on the distribution network and maintenance, but apparently nothing to cut greenhouse gas emissions.

The NGO Beyond Zero Emissions (BZE) has produced a report, *Zero Carbon Australia Stationary Energy Plan*, which describes and costs a proposal to enable Australia to change to 100% renewable energy by 2020, using only ‘proven and commercialised technologies’ (Beyond Zero Emissions 2009). This effectively confines the scheme to using wind and solar power with storage – including pumped hydro power – and some biomass; but not geothermal, other biofuels, nor tidal or wave power. It does not include major grid extensions into remote Australia, apart from a dual link from Port Augusta to the Western Australia grid. It envisages all-electric public and private transport from renewable sources. This proposal estimates net additional investment costs for the stationary energy transition at some AU\$200 billion over 10 years, in the absence of future carbon prices or escalating oil prices, which they claim would make the scheme economically favourable.

This proposal has been briefly reviewed by Diesendorf (2010), who criticises its demanding timescale of a single decade, and its costings, to which I would add its neglect of other renewable energy resources. Nevertheless, it used much professional advice and has stimulated debate. Diesendorf also objects to the BZE’s linking of the Western Australian grid to South Australia as not economical, favouring natural gas rather than the time zone difference to cope with peak demand. However, the BZE’s claimed transmission loss of only some 6% makes such a link look attractive.

The potential for geothermal energy worldwide is huge (Grimsson 2007), as it is in Australia (Chopra and Holgate 2005).

It is already well on the way to development in Australia with companies such as Geodynamics Ltd (see <http://www.geodynamics.com.au>, accessed 6 October 2011), Torrens Energy (see www.torrensenergy.com, accessed 6 October 2011) and Petratherm (see www.petratherm.com.au, accessed 6 October 2011) working on preliminary drilling and site testing. Geodynamics is exploring geothermal resources in sites in the Cooper Basin, while Torrens Energy and Petratherm have sites in or near the Flinders Ranges. They are also exploring other sites in less remote areas.

Tidal energy also has large potential in coastal areas of northern and western Australia where tidal ranges are large. The Blue Mud Bay decision (High Court 2008), which recognises traditional owners’ property rights in tidal waters, gives Aboriginal people a large economic stake in any tidal power developments.

The 18 June 2011 announcement that the Australian federal government has awarded funding to two large-scale solar energy projects near Chinchilla (Queensland) and Moree (New South Wales), at 250 and 150 MW respectively, adds credibility to the potential. These are both located close to outlying grid connections. However, if the social co-benefits are taken into account, other developments requiring grid extensions could also be funded. Indeed, part of the case for funding these two developments was local employment, with the Moree Solar Farm consortium stating that it will provide jobs both during construction and ongoing, and that it ‘is committed to working with the local community, employment agencies and training bodies to provide Aboriginal employment and opportunities’. Ongoing jobs are stated to include ‘site managers, security staff, maintenance and administration personnel, and there is a commitment ‘to provide indigenous employment opportunities’ (Moree Solar Farm 2011).

Employment and income potential from renewable energy

The crucial issue regarding the development of renewable energy resources in remote Australia from the social benefits viewpoint is: what employment and income benefits would such development provide, and can that be accounted for in terms of a national economic benefit?

A sizeable literature exists on the potential economic opportunities created by renewable energy developments (e.g. Khosla 2007; ACF and ACTU 2008; Hatfield-Dodds *et al.* 2008; Mills and Morgan 2008; UNEP 2008; European Commission 2009; Caperton and Hersh 2011; Jobs21! 2011). Some of these reports claim that millions of jobs can be created from the large-scale deployment of energy efficiency and renewable energy in Europe, the US and elsewhere, although much of that employment would be in the manufacture and export of equipment such as solar cells. A recent report by the IPCC on renewable energy discusses these issues at length (IPCC 2011).

Jobs21! in a US context, states that ‘a 21st century economy will require building a cleaner, more efficient economy. And right now, China, Germany and other countries are already building the industries that will get them there – and creating the jobs that come with it. If we don’t act now, we risk being left behind in the biggest job-creating opportunity of our generation.’ That may well apply to Australia as well.

One of the most applicable reports to the present proposal is a Californian study by Stoddard *et al.* (2006). They found that for each 100 MW of generating capacity, concentrated solar power would result in 94 permanent operations and maintenance jobs, compared with 56 for combined cycle gas and 13 for simple cycle gas turbine plants. At least two other reports have given similar estimates: one in *CSP Today* in 2008 (unfortunately no longer on their website) estimated 100 ongoing jobs per 100 MW, while Greenpeace/ESTIA/IEA (2005) suggests 120 permanent jobs in maintenance and operations per 100 MWe unit. As already stated in the case of the Moree Solar Farm, such jobs would cover a range of ongoing activities, which will obviously depend on the particular resource and technology employed.

The ACF and ACTU (2010) study, based on modelling by the National Institute of Economic and Industry Research, estimates that under a 'deep cuts in emissions' scenario, some 3.7 million jobs would be created across the whole Australian economy by 2030 (compared with 3.0 million under a weak action scenario). How many of these jobs would be in remote Australia would of course depend on whether remote renewable energy resources are in fact developed. Hopefully, the present proposal would ensure that an appreciable proportion of new jobs would be in remote areas.

While such estimates depend on the detailed assumptions, they suggest that sizeable direct and ongoing employment opportunities could be created by renewable energy development. There would also be secondary employment opportunities using locally produced heat or power, for example to fire pottery kilns as part of an Aboriginal art industry (Peter Lain, pers. comm.), production of liquid fuel for transport, or even pumping and desalination of water for industrial or agricultural purposes. Such local developments have already been pioneered on a small scale through the Bushlight program of the Centre for Appropriate Technology (see www.bushlight.org.au/, accessed 6 October 2011 and www.icat.org.au, accessed 6 October 2011).

Social co-benefits and involvement of Aboriginal communities

One of the most important economic and social co-benefits of a large renewable energy industry in remote areas of Australia, especially in or near remote Aboriginal communities, is the direct or indirect provision of income and employment for local people where they are, rather than potential workers having to move to distant places. Economic disadvantage is only one aspect of Aboriginal disadvantage (Hunter 2008). However, where economic development programs are culturally appropriate and supported in the long term, both financially and by Aboriginal community leadership, they potentially help build resilient economic systems and communities less dependent on government-funded social welfare (Sullivan 2006).

Many remote Aboriginal communities, (which in most cases are growing in population), and town camps on the edge of larger non-Indigenous communities have suffered from social problems such as alcoholism and other substance abuse, violence and social discord. This has sometimes been attributed to their Aboriginal cultural heritage. This may be partly the case with some cultural elements inconsistent, at least in part, with modern economic society. Voluntary evolution of culture to include practices

appropriate to modern society and its economic practices may well be necessary (Pearson 2009; Sutton 2009). However, lack of economic opportunity or resources is also a key underlying causal factor in many communities.

Some people who do not value Aboriginal cultural identity argue that abandonment of remote 'unviable' Aboriginal communities will separate Aborigines from their allegedly unsustainable and dysfunctional traditions and practices and force them into the mainstream and supposedly more sustainable society (Bennelong Society 2006; Hughes 2007). However, continuing problems in larger regional centres suggest that this is not the case. Indeed, in many of these regional centres unemployment is rife and welfare dependency common. Such 'welfare colonialism' has been the subject of much scholarly and public debate (Pearson 2009; Sutton 2009; and comments by Nicholls *et al.* 2009). Recently this debate has centred on the federal Government's 'intervention' in the Northern Territory and the role of welfare payments and availability of alcohol.

The widespread occurrence of similar social problems in other low-resource low-income communities in other countries, irrespective of cultural background, suggests that for Aboriginal Australians, social problems are at least partly the result of social disadvantage (including social and economic disempowerment), rather than peculiarly Indigenous cultural traditions. The American sociologist Oscar Lewis reached a similar conclusion regarding poor communities of Mexicans, Afro-Americans and Puerto Ricans in the US as long ago as the 1960s (Lewis 1967; Pittock 1977). Lewis dignified this poverty syndrome as a 'culture of poverty'. Lewis' terminology and categorisation has been contentious (Coward *et al.* 1974; Gajdosikiene 2004). However, his observation that unemployment in such communities often led to lack of self-respect, substance abuse and family violence, with women often having to assume the role of breadwinner or matriarch, remains true in many poverty situations. This is moderated in many remote 'homeland' Aboriginal communities by the traditional roles of Aboriginal men and women as keepers of cultural tradition, but these roles are often broken down in fringe-dwelling communities distant from the Aboriginal home country.

While proper bi-cultural education is important (Pearson 2009), and prohibition of alcohol may treat one important problem (Sutton 2009), lack of economic resources is an underlying factor in many Aboriginal communities. The case for recognition of Aboriginal land rights was indeed fought both to preserve Aboriginal relationships with the land both for cultural reasons and to provide an economic base (Pittock 1972). As I wrote in 1971:

The continuing historical process of dispossession has deprived the Aboriginal people, and their part-Aboriginal descendents, of both their cultural heritage and their economic independence. This is at the root of the present situation of Aboriginal poverty and alienation. The Aboriginal and part-Aboriginal people cannot be successfully integrated into an affluent twentieth century society unless they have some economic capital and bargaining power, and indeed a stake in the emerging multi-racial Australian community.

Unfortunately, most remaining un-alienated Aboriginal land holdings were left alone following European settlement essentially because they lacked substantial economic value to Europeans at the time. Any economic value was in traditional hunting and gathering, and possibly in running cattle. More recently some have gained economic value as tourist destinations or as the base for evolving Aboriginal art and craft enterprises. It is only now that their value as sites for much needed renewable energy enterprises is becoming apparent.

This analysis highlights the importance of utilising opportunities to provide meaningful employment and income in regional and remote communities in order to break down the material poverty which is crippling Aboriginal society. These communities need to become economically viable, thus enabling Aborigines to rebuild functional societies and at the same time retain close links with traditional country. This has already happened in some Aboriginal and Torres Strait Islander communities, especially through the development of tourism and arts and crafts industries. These include regionally specific modern traditions in painting, fabric and even pottery. Based on examples such as the Southwest Indians in the US, I advocated such cultural adaptations over four decades ago (Pittock 1967).

As the Bushlight initiatives have already demonstrated on a small scale, the rich resources of renewable energy that are available in many remote areas of Australia provide modern Aboriginal communities with opportunities for earning income, thus providing some additional employment and possibly long-term viability of their communities. What is being advocated here is building further on Bushlight's very successful initiatives, but on a larger scale. In view of the large economic and technological investments necessary, clearly such larger developments will need to occur with the joint participation of Aboriginal communities and outside commercial interests. Indeed, such large-scale developments will not be successful unless they are fully supported by Aboriginal communities and by government agencies.

Clearly, existing or proposed remote non-Indigenous enterprises should be encouraged or required to provide training or apprenticeships to local Aboriginal people to be employed preferentially as staff in manual or preferably skilled jobs of maintenance and construction. This is already a feature of the work of the Indigenous Land Corporation (NILS 2011), Indigenous Business Australia (IBA 2008), and well developed in the *Australian Employment Covenant* (see www.fiftythousandjobs.com.au, accessed 6 October 2011), which is a private sector initiative supported by the federal government, although this does not specifically encourage local employment.

Job opportunities in developments far removed from traditional communities may well not be taken up in large numbers by Aboriginal people or would have the adverse effect of removing young potential leaders from their home communities. This places them outside the restraints and comforts of family and traditional communities and the tutelage and oversight of their elders.

In contrast to mining and tourism, which are both location-specific industries that in many instances cannot readily be co-located with existing remote settlements, renewable energy resources are extremely widespread in remote areas of Australia. Development of these renewable resources can in many cases be

located within easy commuting distance of existing remote settlements, whether Aboriginal, Torres Strait Islander or non-Indigenous.

Renewable energy development on a large scale would thus provide an opportunity to simultaneously solve the two central problems of reducing carbon emissions and solving social problems related to lack of employment by developing a diverse local economy based on people, skills and energy resources.

Research questions arising

Adaptation needs and solutions

The broad issues here are well spelled out in the IPCC (2007b) report and in the 41">Green *et al.* (2009) report quoted above. These will need to be tackled individually for many communities, depending on their location and vulnerability to coastal or riverine flooding, present and future climatic conditions, and existing infrastructure, including housing, roads, and communication links. A lot will depend on the provision of local and outside resources to tackle often expensive adaptation measures such as building levee banks, relocation to higher ground, or strengthened or otherwise modified buildings and other infrastructure. Water supply and medical facilities will also need upgrading. Measures arising from new developments such as large-scale renewable energy production could well change the nature of many communities.

Economics of large-scale renewable energy with grid extensions

This has been examined in parts by such bodies as the Australian Energy Market Operator (AEMO 2009a, 2009b) and Beyond Zero Emissions (2009), and in order-of-magnitude estimates by Seligman (2009). It is important that such economic assessments capture the advantages of a national grid with large time zone and north-south differences that can offset seasonal variations between monsoon and other regions, using the full range of renewable resources including solar, wind, tidal, hydro and geothermal, with various energy storage systems.

This might well include phased developments radiating out from the existing grid to the margins, for example, into Cooper Basin, Port Augusta, and then on to be truly national with links to Western Australia, Alice Springs and Darwin. Such calculations should also explore economies from co-development with the NBN, sharing infrastructure such as easements, transmission towers and cabling as far as that is possible.

Associated with its 2007 Annual Report, the major engineering company Worley Parsons revealed on its website a plan to build 34 advanced solar thermal power stations by 2020, each 250-MW peak output, to supply 50% of the proposed Australian renewable energy target of 20% of all Australian electricity by 2020. It planned to do this in collaboration with some of the leading companies operating in Australia, including Rio Tinto, BHP Billiton, Woodside and Wesfarmers. Perhaps due to the global economic crisis and the failure of the Rudd federal government to go ahead with its proposed emissions trading scheme, this solar power idea seems to have been dropped. However, as late as 2009 Worley Parsons was working on a solar flagship proposal for Port Augusta 'that we can extend to a solar gas hybrid power station and then to solar geothermal in the

Cooper Basin' (Peter Meurs in ATSE 2009). It also has a major role in constructing the first solar commercial central receiver system in the US at Ivanpah in California with a 400-MW capacity, and could resurrect other Australian solar power projects if a price is put on carbon dioxide emissions.

Geoff Wearne of Worley Parsons (pers. comm. June 2010) said:

The key driver for Worley Parsons is to have a solar facility constructed to prove that it works. The problem at the moment is the cost of electricity generated via solar versus that from fossil fuels. Unless there is a high price on carbon, Origin Energy and others will continue to build gas facilities that will ensure that solar is not economic.

In the present financial climate such large-scale solar energy developments seem to depend in part on government incentives such as a price on carbon emissions or specific grants. Perhaps a national electricity grid is an essential prerequisite for business investment in large-scale and widely dispersed renewable energy.

Alternative solar technologies are also an issue and need further investigation. See for example the ongoing comment and discussion in *CSP Today* at www.csptoday.com, accessed 6 October 2011. This is right in the province of the Desert Knowledge Australia Solar Centre.

Water

Water use and supply is a key issue in remote Australia, so water needed for cooling or cleaning solar (and geothermal) plants is critical, as it is for fossil fuel power generation also (Hightower and Pierce 2008; Evans *et al.* 2009; Maheu 2009). This will depend on the particular technology employed, and solar power could, in some locations, be used to desalinate bore- or sea water where needed. Part of the European Desertec Foundation proposals is to use solar power for large-scale desalinisation in near-coastal areas of North Africa. For most regions, however, dry cooling of solar power installations will become the norm, despite small losses in efficiency, but the problem may be more serious for biofuels in some locations.

Job opportunities in construction of and ongoing renewable energy projects and skill levels needed

A key question is how many jobs would be created both in manufacturing and in maintenance, in urban centres and remote areas, and the level of skills required. A related question is how many of these jobs would or could be filled by local people in remote areas and how many from people brought in from elsewhere on a temporary basis, as is the case with many mining developments. Regional social benefits would depend in large measure on giving preference to locals and their on-the-job training, so the acceptability of this to businesses and local communities needs to be explored.

In the case of Aboriginal communities the acceptability or desirability of such developments among local communities is a key question, both in terms of job opportunities and of having major infrastructure developments on their traditional land. The acceptability and impact of sizeable numbers of workers coming in from outside, possibly living in camps or bringing their families, would need to be explored. And local communities

would need to have the final say on exact location in relation to existing facilities and sacred sites.

An economic assessment of the social benefits, such as avoided costs of unemployment benefits, subsidised housing and health provisions, and of other measures to cope with the symptoms of poverty, seems desirable. Given that tens of thousands of Australians living in remote areas are involved, such sums could be considerable and could be a powerful argument for such developments. Indeed, a preliminary study by Access Economics (2009) for the Desert Knowledge CRC estimated a possible benefit of closing the economic gap between Aboriginal and non-Indigenous Australians by 2029 of about AU\$2.9 billion, and some 22 000 extra jobs throughout Australia. Clearly, increased direct or indirect local employment and income from exploitation of large-scale renewable energy would contribute a significant proportion of this amount, but this needs further study.

How to relate large-scale renewable energy development to Aboriginal communities

Involvement of and support from Aboriginal communities is essential for any successful development. This will only happen if key organisations such as the Central and Northern Land Councils, the North Australian Indigenous Land and Sea Management Alliance, the Centre for Appropriate Technology including Bushlight, and others want to be involved. Such bodies already have many successful projects under their belts, considerable relevant skills, and could mobilise people and resources.

This should not be a top-down only process. Local communities need to be involved in the planning and in encouraging the acquisition of relevant skills at the local level through appropriate schooling and scholarships. As in the case of Aboriginal involvement in the tourist industry, each community will be a different case, with different organisations, resources, skills and interests. Account must be taken of their diverse needs and social conditions (e.g. FRDC 2004) and the CSIRO 'Indigenous Engagement Strategy' (see www.csiro.au/resources/Indigenous-Engagement-Strategy.html, accessed 6 October 2011) may be a useful guide. As one training conference blurb recently put it 'it is time to stop the process of doing "it" to people or for people and to start doing "it" with people'.

Off-grid possibilities

Given that many renewable energy resources are in remote places and in some cases it may not be economic, at least initially, to link these to the national grid, it may well be desirable to develop some of these resources off-grid. This could be to provide local power for mining and refining activities, powering railways from mines to remote ports, or for other local energy-consuming activities. These might include potteries (as at Hermannsburg) or generation of vehicular fuels such as charging batteries, electrolysis to generate hydrogen for fuel cells, or desalinisation of sea water or saline bore water for local use or even irrigated high-value agriculture, for example, for biofuels. Generation of liquid ammonia as a vehicular fuel from hydrogen and atmospheric nitrogen is another possibility worth examination (AFN 2010; NH3 2010; see also www.agmrc.org/renewable_energy/renewable_energy/

ammonia_as_a_transportation_fuel.cfm, accessed 25 October 2011).

Such possibilities need careful technological and economic evaluation.

Development of overseas markets?

As discussed above, there is a real prospect of large-scale renewable energy from North Africa and the Middle East being used to power Europe via HVDC cables (TREC 2007). Desertec-Australia (2010) and others have suggested similar development in Australia aimed at exporting electricity, or even hydrogen gas generated by electrolysis of water, to Asia via the Indonesian grid or pipelines.

To some this seems a grandiose pie-in-the-sky idea. Counter arguments are that Indonesia has many renewable energy prospects of its own, and that any linking cable would be too expensive. However, it needs careful evaluation, not as an immediate prospect, but as a possible future, perhaps decades ahead. The possibility needs to be taken into account in the overall design of a growing renewable energy development, possibly with one end of any national grid conveniently located for a future link to Indonesia. If natural gas can be exported in large quantities to Asia by ship or by pipeline, why not renewable energy?

Conclusions

Climate change and a future oil shortage will have large potential impacts on remote/desert Australia. This is both a challenge and an opportunity. It will require both adaptation to a changing climate and energy supply situation, and provide an opportunity to exploit the region's huge potential renewable energy resources.

Prevailing thinking suggests that exploitation of renewable energy resources will focus primarily or exclusively on inland areas near the existing electricity grids, with only minor grid extensions. However, the use of HVDC cabling for long distance transmission with very low-energy losses changes the economics considerably. This is especially so if there are significant co-benefits in providing or enabling employment and income in remote areas.

There are also big advantages in a national electricity grid that would allow the 3-h time difference between western and eastern Australia to be exploited to help cover peak demands, and a north-south spread that will partly exploit the seasonal differences in climate. The economics of transmission with HVDC cables may well swing the balance against widespread use of gas-fired power stations to meet peak demand. In any case, gas usage would still lead to increasingly unacceptable levels of greenhouse gas emissions unless these can be captured and stored (with additional costs).

A key uncertainty is how many and what sort of ongoing jobs large-scale renewable energy installations would provide. These would be both direct, such as in site management, maintenance, security and administration; and indirect, through the ready availability of sufficient energy for local manufacturing or other activities.

On a local smaller scale Centre for Appropriate Technology and Bushlight, in collaboration with local communities, have already demonstrated the existence of some local employment opportunities, both direct and indirect. What is needed now is to

expand this activity by scaling it up. Additionally, if such development takes place by agreement with local communities on Aboriginal land, there would likely be some compensation in the form of a rent or percentage of income produced. This may provide a significant income source for local communities.

Much more research is need on optimum design and economic assessment, but the potential is there. It is up to existing institutions and communities to get together to develop these, with the cooperation of outside businesses interested in such developments. Recent developments subsidised by governments, especially Torresol (2011) in Spain and others in the US (see ongoing updates on CSP Today at <http://social.csptoday.com>, accessed 6 September 2011), suggest that this is now possible. It will take decades to evolve fully, but a start needs to be made.

Various bodies already exist to foster Aboriginal economic development, including the Indigenous Land Corporation (NILS 2011), Indigenous Business Australia (IBA 2008) and the Centre for Aboriginal Economic Policy Research (e.g. Altman and Dillon 2004; Altman *et al.* 2007). With prompting from Aboriginal organisations, these bodies may well assist, but express government funding of infrastructure, or other subsidies and incentives, may be the key to corporate business investment.

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References

- AAS (Australian Academy of Science) (2010a). The Science of Climate Change: Questions and Answers. Available at: www.science.org.au/reports/index.html (accessed 2 September 2011).
- AAS (Australian Academy of Science) (2010b). Australia's Renewable Energy Future. (Eds M. Dopita and R. Williamson). Available at: www.science.org.au/reports/index.html (accessed 2 September 2011).
- Aboriginal Carbon Fund (2011). Available at: www.centrefarm.com/11-conservation-economy.html (accessed 2 September 2011).
- Access Economics (2009). Economic impact of closing the Indigenous gap in remote and very remote Australia. Report for the Desert Knowledge CRC, Alice Springs, NT.
- ACF and ACTU (Australian Conservation Foundation and the Australian Council of Trade Unions) (2008). 'Green Gold Rush: How ambitious Environmental Policy can make Australia a Leader in the Global Race for Green Jobs.' Australian Conservation Foundation and the Australian Council of Trade Unions. Available at: www.acfonline.org.au/uploads/res/Green_Gold_Rush_final.pdf (accessed 2 September 2011).
- ACF and ACTU (Australian Conservation Foundation and the Australian Council of Trade Unions) (2010). 'Creating Jobs – Cutting Pollution: The Roadmap for a Cleaner, Stronger Economy.' Available at: www.acfonline.org.au/uploads/res/ACF_Jobs_report_190510.pdf (accessed 2 September 2011).
- AEMO (2009a). 'Network Extensions to Remote Areas, Part 1 – Planning Considerations. Available at: www.aemo.com.au (accessed 2 September 2011).
- AEMO (2009b). Network Extensions to Remote Areas, Part 2 – Innamincka Case Study. Available at: www.aemo.com.au (accessed 2 September 2011).

- AFN (2010). Ammonia Fuel Network. Available at: www.nh3fuelassociation.org/ (accessed 2 September 2011).
- Altman, J. C., and Dillon, M. C. (2004). 'A Profit-related Investment Scheme for the Indigenous Estate.' CAEPR Discussion Paper No. 270/2004. (Centre for Aboriginal Economic Policy Research: Canberra.)
- Altman, J. C., Buchanan, G., and Larsen, L. (2007). 'The Environmental Significance of the Indigenous Estate: Natural Resource Management as Economic Development in Remote Australia.' CAEPR Discussion Paper No. 286/2007. (Centre for Aboriginal Economic Policy Research: Canberra.)
- ASPO (2010). Association for the Study of Peak Oil and Gas. Available at: www.peakoil.net (accessed 2 September 2011).
- ATSE (2009). Rising to the challenge of climate change. In: '32nd ATSE National Symposium: Future Proofing Australia'. Australian Academy of Technological Sciences and Engineering. Available at: www.atse.org.au/resource-centre/ATSE-Reports/Climate-Change-Impacts/ (accessed 2 September 2011).
- Bennelong Society (2006). Leaving Remote Communities Conference. (Bennelong Society: Sydney.) Available at: www.bennelong.com.au (accessed 2 September 2011).
- Beyond Zero Emissions (2009). Zero Carbon Australia Stationary Energy Plan. Available at: www.beyondzeroemissions.org/zero-carbon-australia-2020 (accessed 25 October 2011).
- Bleich, J. (2010). Gulf disaster underscores challenge. *The Age*, 12. Melbourne.
- Bruce, L., McClintock, J., and Holbrook, J. (2008). Ammonia Fuel – The Other Hydrogen Future. Available at: <http://peakoil.blogspot.com/search?q=ammonia> (accessed 2 September 2011).
- Caperton, R. W., and Hersh, A. (2011). Putting America Back to Work with Clean Energy Productivity, Economic Efficiency, and the Promise of Green Jobs. Available at: www.americanprogress.org/issues/2011/03/pdf/green_jobs.pdf (accessed 25 October 2011).
- Chopra, P., and Holgate, F. (2005). A GIS Analysis of Temperature in the Australian Crust. In 'Proceedings World Geothermal Congress 2005'. Antalya, Turkey. Proceedings available from iga@hs-bochum.de.
- Clean Energy Future Policy (2011). Available at: www.cleanenergyfuture.gov.au/clean-energy-future/ (accessed 25 October 2011).
- Climate Institute (2010). Renewable Energy Investment and Abatement Opportunities in Australia. Bloomberg New Energy Finance, commissioned by The Climate Institute and Westpac. Available at: www.climateinstitute.org.au/our-publications/reports (accessed 2 September 2011).
- Climate Works Australia (2010). Low Carbon Growth Plan for Australia. Available at: www.climateworksaustralia.org (accessed 2 September 2011).
- Coward, B. E., Feagin, J. R., and Williams, J. A. Jr (1974). The culture of poverty debate: some additional data. *Social Problems* **21**, 621–634. doi:10.1525/sp.1974.21.5.03a00030
- CSIRO (2011a). 'Climate Change: Science and Solutions for Australia.' (CSIRO Publishing: Melbourne.)
- CSIRO (2011b). Understanding Tropical Cyclones. Available at: www.csiro.au/org/Tropical-cyclones-vgnextfmt-print.html (accessed 2 September 2011).
- CSIRO and Australian Bureau of Meteorology (2007). 'Climate Change in Australia.' Technical Report 2007. (CSIRO: Canberra.)
- CSIRO and Australian Bureau of Meteorology (2010). *State of the Climate*, joint statement. Available at: www.csiro.au/files/files/pvfo.pdf (accessed 2 September 2011).
- Deffeyes, K. S. (2001). 'Hubbert's Peak: The Impending World Oil Shortage.' (Princeton University Press: Princeton, NJ.)
- Department of Resources, Energy and Tourism (2010). 'Australian Energy Resources Assessment.' Geoscience Australia and ABARE. Available at: www.abares.gov.au/publications_remote_content/publication_topics/energy (accessed 6 September 2011).
- Desertec (2011). Desertec Foundation. Available at: www.desertec.org/ (accessed 2 September 2011).
- Desertec-Australia (2010). Australia: "Clean Energy Superpower". Available at: www.desertec-australia.org (accessed 2 September 2011).
- Diesendorf, M. (2010). Ambitious target does not quite measure up. *Ecoss* **157**, 30.
- European Commission (2009). The Impact of Renewable Energy Policy on Economic Growth and Employment in the European Union. Available at: http://ec.europa.eu/energy/renewables/studies/doc/renewables/2009_employ_res_summary.pdf (accessed 5 September 2011).
- Evans, A., Strezov, V., and Evans, T. J. (2009). Assessment of sustainability indicators for renewable energy technologies. *Renewable & Sustainable Energy Reviews* **13**, 1082–1088. doi:10.1016/j.rser.2008.03.008
- Fowler, A. M., and Hennessy, K. J. (1995). Potential impacts of global warming on the frequency and magnitude of heavy precipitation. *Natural Hazards* **11**, 283–303. doi:10.1007/BF00613411
- FRDC (2004). 'Water: a report on the provision of water and sanitation in remote Aboriginal and Torres Strait Islander communities.' Federal Race Relations Commissioner. (AGPS: Canberra.)
- Gajdosikienė, I. (2004). Oscar Lewis' culture of poverty: critique and further development. *Sociology. Thought and Action* **01**, 88–96.
- Glennon, R., and Reeves, A. M. (2010). Solar energy's cloudy future. *Arizona Journal of Environmental Law and Policy* **1**, 91–137.
- Global Energy Systems (2010). Formerly the Uppsala Hydrocarbon Depletion Study Group. Available at: www.fysast.uu.se/ges/ (accessed 2 September 2011).
- Gordon, H. B., Whetton, P. H., Pittock, A. B., Fowler, A. M., and Haylock, M. R. (1992). Simulated changes in daily rainfall intensity due to the enhanced greenhouse effect: implications for extreme rainfall events. *Climate Dynamics* **8**, 83–102. doi:10.1007/BF00209165
- Green, D., Jackson, S., and Morrison, J. (Eds) (2009). 'Risks from Climate Change to Indigenous Communities in the Tropical North of Australia.' (Department of Climate Change and Energy Efficiency: Canberra.)
- Greenpeace/ESTIA/IEA (2005). Concentrated Solar Thermal Power – Now! Available at: www.greenpeace.org (accessed 2 September 2011).
- Grimsson, O. (2007). A Clean Energy Future for the United States: The Case for Geothermal Power. Testimony to US Senate, 26 September 2007. Available at: http://energy.senate.gov/public/_files/testimony.pdf (accessed 2 September 2011).
- Hatfield-Dodds, S., Turner, G., Schandl, H., and Doss, T. (2008). 'Growing the Green Collar Economy: Skills and Labour Challenges in Reducing our Greenhouse Emissions and National Environmental Footprint.' Report to the Dusseldorf Skills Forum, June 2008. (CSIRO Sustainable Ecosystems: Canberra.)
- Hennessy, K. J., Gregory, J. M., and Mitchell, J. F. B. (1997). Changes in daily precipitation under enhanced greenhouse conditions. *Climate Dynamics* **13**, 667–680. doi:10.1007/s003820050189
- High Court (2008). Northern Territory of Australia v Arnhem Land Aboriginal Land Trust [2008] HCA 29 (30 July 2008). Available at: www.atns.net.au/agreement.asp?EntityID=4729 (accessed 2 September 2011).
- Hightower, M., and Pierce, S. A. (2008). The energy challenge. *Nature* **452**, 285–286. doi:10.1038/452285a
- Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., Harvell, C. D., Sale, P. F., Edwards, A. J., Caldeira, K., Knowlton, N., Eakin, C. M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R. H., Dubi, A., and Hatziolos, M. E. (2007). Coral reefs under rapid climate change and ocean acidification. *Science* **318**(5857), 1737–1742. doi:10.1126/science.1152509
- Hughes, H. (2007). 'Lands of Shame: Aboriginal and Torres Strait Islander "Homelands" in Transition.' (Centre for Independent Studies: Sydney.)

- Hunter, P. (2008). Indigenous Social Exclusion: insights and challenges for the concept of social inclusion. In: 'Brotherhood of St Laurence, Special Inclusion Down Under Symposium Proceedings'. Available at: www.bsl.org.au/pdfs/Hunter_symposium_paper_26Jun08.pdf (accessed 2 September 2011).
- IBA (2008). Indigenous Business Australia, Corporate Plan 2008–2011. Available at: www.iba.gov.au (accessed 5 September 2011).
- IEA (2010). International Energy Agency, Energy Technology Perspectives 2010: Scenarios and Strategies to 2050. Available at: (accessed 2 September 2011).
- IPCC (Intergovernmental Panel on Climate Change) (2007a). 'Climate Change 2007, The Physical Science Basis.' (Cambridge University Press: Cambridge, UK.) Available at: www.ipcc.ch (accessed 2 September 2011).
- IPCC (Intergovernmental Panel on Climate Change) (2007b). 'Climate Change 2007, Impacts, Adaptation and Vulnerability.' (Cambridge University Press: Cambridge, UK.) Available at: www.ipcc.ch (accessed 2 September 2011).
- IPCC (Intergovernmental Panel on Climate Change) (2011). Special Report on Renewable Energy Sources and Climate Change Mitigation. Available at: www.ipcc.ch (accessed 6 September 2011).
- Jobs21! (2011). JOBS21! Good Jobs for the 21st Century: A BlueGreen Alliance Blueprint to Solve the Jobs Crisis. Available at: www.bluegreenalliance.org/ (accessed 5 September 2011).
- Khosla, V. (2007). Statement of Vinod Khosla to Committee on Environment and Public Works hearing on 'Green Jobs Created by Global Warming Initiatives'. Available at: http://epw.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=d9dd3114-e5a9-42d4-90cf-53db6acf89d8 (accessed on 5 September 2011).
- Lewis, O. (1967). 'La Vida.' (Secker and Warburg: London.)
- Maheu, A. (2009). Energy choices and their impacts on demand for water resources, McGill University. Available at: http://unisfera.org/?id_article=519&pu=1&ln=1 (accessed 2 September 2011).
- Mills, D. R., and Morgan, R. G. (2008). Solar thermal electricity as the primary replacement for coal and oil in U.S. generation and transportation. Available at: www.ausra.com/pdfs/SolarPACESMills-Morgan.pdf (accessed 2 September 2011).
- Moree Solar Farm (2011). Frequently Asked Questions, press release, 18 June 2011. Available at: www.moreesolarfarm.com.au/press (accessed 6 October 2011).
- NH3 (2010). Ammonia FAQs. Available at: www.nh3car.com/FAQ1.htm (accessed 2 September 2011).
- NBN (2010). National Broadband Network. Available at: <http://www.australia.gov.au/nbn> or www.dbcde.gov.au (accessed 2 September 2011).
- Nicholls, C., Sarra, C., Abbott, T., Shergold, P., Sutton, P., Chaney, F., Caro, J., Leigh, A., and Pearson, N. (2009). Individual comments re Pearson (2009). *Quarterly Essay* 36, 93–114.
- NILS (2011). Indigenous Land Corporation, *National Indigenous Land Strategy 2007–2012*. Available at: www.ilc.gov.au (accessed 5 September 2011).
- NOAA (2011). Trends in atmospheric carbon dioxide. Available at: www.esrl.noaa.gov/gmd/ccgg/trends/ (accessed 2 September 2011).
- Ölz, S., and Beerepoot, M. (2010). Deploying Renewables in Southeast Asia: Trends and Potentials. IEA Energy Papers, No. 2010/06. Available at www.iea.org (accessed 26 October 2011).
- Origin Energy (2010). PNG and Qld Governments support studies to progress PNG renewable energy project for PNG and Qld. ASX/Media Release, 15 September. Available at: www.originenergy.com.au/news/article/asxmedia-releases/1222 (accessed 2 September 2011).
- Pearson, N. (2009). Radical hope: education and equality in Australia. *Quarterly Essay* 35, 1–105.
- Pew Center (2009). The Emails from the University of East Anglia's Climatic Research Unit. Available at: www.pewclimate.org/docUploads/east-anglia-cru-hacked-emails-12-09-09.pdf (accessed 2 September 2011).
- Pittock, A. B. (1967). Aborigines and the tourist industry. *The Australian Quarterly* 39, 87–95. doi:10.2307/20634152
- Pittock, A. B. (1972). Aboriginal Land Rights. In: 'Racism: The Australian Experience, Vol. 2: Black Versus White'. (Ed. F. S. Stevens.) pp. 188–208. (Australia and New Zealand Book Co.: Sydney.)
- Pittock, A. B. (1977). Towards a Multi-Racial Society. In: 'Racism: The Australian Experience'. 2nd edn. Vol. 3. (Eds F. S. Stevens and E. P. Wolfers.) pp. 240–263. (Australia and New Zealand Book Co.: Sydney.)
- Pittock, B. (2003). 'Climate Change: An Australian Guide to the Science and Potential Impacts.' (Australian Greenhouse Office: Canberra.)
- Pittock, B. (2009a). 'Climate Change: The Science, Impacts and Solutions.' 2nd edn. (CSIRO Publishing: Melbourne.) Available at: www.publish.csiro.au/nid/20/pid/6010.htm (accessed 2 September 2011).
- Pittock, B. (2009b). Can solar variations explain variations in the Earth's climate? *Climatic Change* 96, 483–487. doi:10.1007/s10584-009-9645-8
- PriceWaterhouseCoopers (2010). Measuring progress towards 100% renewable electricity in Europe and North Africa. Available at: www.supersmartgrid.net/ (accessed 2 September 2011).
- Riedy, C. (2007). 'Energy and Transport Subsidies in Australia.' A report to Greenpeace Australia Pacific. (Institute for Sustainable Futures, University of Technology: Sydney.)
- Rotstayn, L. R., Cai, W., Dix, M. R., Farquhar, G. D., Feng, Y., Ginoux, P., Herzog, M., Ito, A., Penner, J. E., Roderick, M. L., and Wang, M. (2007). Have Australian rainfall and cloudiness increased due to the remote effects of Asian anthropogenic aerosols? *Journal of Geophysical Research* 112, D09202. doi:10.1029/2006JD007712
- Seligman, P. (2009). 'Australian Sustainable Energy – By the Numbers.' (Melbourne Energy Institute: Melbourne.) Available at: www.energy.unimelb.edu.au (accessed 2 September 2011).
- Service, R. F. (2005). Is it time to shoot for the sun? *Science* 309, 548–551. doi:10.1126/science.309.5734.548
- Stoddard, L., Abiecunas, J., and O'Connell, R. (2006). Economic, Energy, and Environmental Benefits of Concentrating Solar Power in California. National Renewable Energy Laboratory, Subcontract Report NREL/SR-550-39291, April 2006. Available at: www.nrel.gov (accessed 2 September 2011).
- Sullivan, P. (2006). 'Indigenous Governance.' AIATSIS Research Discussion Paper No. 17. (Australian Institute of Aboriginal and Torres Strait Islander Studies: Canberra.)
- Suppiah, R., Hennessy, K. J., Whetton, P. H., McInnes, K., Macadam, I., Bathols, J., Ricketts, J., and Page, C. M. (2007). Australian climate change projections derived from simulations performed for the IPCC 4th Assessment Report. *Australian Meteorological Magazine* 56, 131–152.
- Sutton, P. (2009). 'The Politics of Suffering.' (Melbourne University Press: Melbourne.)
- Torresol (2011). Torresol Energy Investments. Available at: www.torresolenergy.com/TORRESOL/home/en (accessed 2 September 2011).
- TREC (2007). Clean Power from Deserts: The DESERTEC Concept for Energy, Water and Climate Security. White Paper. Available at: www.trecers.net/downloads/articles/trec_white_paper.pdf (accessed 2 September 2011).
- UNEP (2008). Green Jobs: Towards Decent Work in a Sustainable, Low-carbon World. United Nations Environment Programme, International Labour Organization, International Organisation of Employers, International Trade Union Confederation. Available at: www.unep.org/labour_environment/features/greenjobs.asp (accessed 2 September 2011).