12 - Renewable Energy and Power Electronics

Renewable energy sources are welcomed by many but without a technological breakthrough or other disruptive change, renewable energy will represent only 5 per cent of the total energy used in Australia by 2020.[1]

Australia has within its territorial boundaries, approximately 800 years of brown coal, 290 years of black coal and around 100 years supply of natural gas.[2] Domestic reserves of oil are depleting rapidly with Australia consuming oil at a rate three times faster than it is discovered.[3] Given these figures, it likely that coal will continue to be the dominant fuel for stationary energy production for many years to come. See Table 12.1 – Share of Electricity Generation by main fuel and technology classes, 1999.

The current costs for non-renewable generation is around $35 to $40 MWh. The Mandatory Renewable Energy Target program (more detail on this program below) provides for the sale of Renewable Energy Certificates. These certificates were trading around $32 per MWh in the third quarter of 2002. This would mean that a renewable generator would need to have a generation cost of no more than $72 MWh to be competitive with grid-connected power generators.[4]

As coal will be the dominant fuel, renewable energy sources will need to compete with this traditional and fuel-rich technology for electricity production on a cost basis. The estimated prices for electricity for domestic consumption range from 21.1 cents per kWh for eastern Victoria to 13.02 cents per kWh in Sydney. Business prices range from 9.61 cents kWh in the Northern Territory through to 5.38 cents per kWh in Melbourne south-east suburbs.[5]

Table 12.1 – Share of Electricity Generation by main fuel and technology classes, 1999[6]

Fuel Type	Percentage
Fossil fuel, other	86.7
Bagasse cogeneration	0.4
Hydro	8.3
Other renewables	0.1
Fossil fuel cogeneration	4.4

In areas that are not grid connected, the prices mentioned above have little relevance. The cost of electricity in these locations will depend upon the selection of the least-cost generating equipment and the total cost of operation. In some locations, electricity generated by wind turbines is proving to be a low-cost option for power supply rivaling grid-connected power. Photovoltaics are also cost effective in premium-power locations. The choice of generation technology will depend upon the least-cost option and renewable energy technology will need to compete at this level.

Issues

Kyoto and CO2 emissions

The Australian Federal Government has chosen not to ratify the Kyoto Protocol that calls for a reduction in the growth of greenhouse gas emissions by 2010. While the protocol has not been ratified, the Federal Government has put into place a number of programs designed to increase the adoption of renewable energy and reduce greenhouse gas emissions.

In 2000, Australia's level of carbon dioxide emissions was 105 per cent of its 1990 emissions level. According to the Kyoto Protocol, in 2010 this will need to be no more than 108 per cent of the 1990 level. However at this stage it appears that emissions will be around 111 per cent in 2010.[7]

One suggestion to encourage the reduction of greenhouse emissions is to place a tax upon the emission of carbon dioxide emissions to reduce consumption. This carbon cost assumes that non-emission technologies would become more competitive and gain greater adoption. However due to the increase in the cost of production and difficulties expected to be faced by some regional economies, the Electricity Supply Association of Australia has suggested that this is an inefficient way to achieve a reduction in greenhouse gas emissions.[8]

Government Programs

The alternative to implementing a tax such as a carbon cost is to change consumption patterns by encouraging specific technologies. The Australian Federal Government has a range of programs (discussed below) that attempt to do this. However, subsidies will never replace rational decision making by purchasers. The technology must be cost effective before large-scale adoption will take place. In terms of this report, the Shared Technology industries will mostly see those technologies that are in full commercial development and not necessarily location specific (such as hot dry rocks - See Box 10.1).

BOX 12.1 – RENEWABLE ENERGY DEVELOPMENT INITIATIVES[9]

Renewable Remote Power Generation Program (RRPGP) *– The Australian Greenhouse Office is implementing a programs to increase the uptake of renewable energy technology in remote areas of Australia not serviced by a main electricity grid. Rebates are provided for up to 50 percent of the capital cost of converting diesel based electricity supplies to renewable energy technologies.*

Renewable Energy Commercialisation Program (RECP) *– This is a five-year competitive grants programs and has made over $50m available to foster the development of the renewable energy industry in Australia. The program supports and promotes strategically important renewable energy technology initiatives that have strong commercial potential.*

Renewable Energy Industry Development Program (REID) *– This is a sub-program of the RECP with $6m in funding. This sub-program will develop a testing and accrediting facility for renewable energy systems.*

Renewable Energy Equity Fund (REEF) *– This fund provides venture capital for small companies seeding to commercialise innovated renewable energy technologies.*

Greenhouse Gas Abatement Program (GGAP) *- The objective of this program is to reduce Australia's net greenhouse gas emissions by supporting activities likely to result in substantial emission abatement, particularly in the first commitment period (2008 - 2012). The program has funding of $400m between July 2000 to June 2004 for projects that would no occur with additional support.*[10]

Overview

In June 2000, the Federal Government released the Renewable Energy Action Agenda coming into effect on 1 April, 2001. This program has the vision of achieving a sustainable and internationally competitive renewable energy industry that will have annual sales of $4 billion by 2010. The Federal Government has committed around $377m in the past five years to support this agenda.[11] See Box 12.1 – Renewable Energy Development Initiatives for information on these programs.

The Federal Government introduced a Mandatory Renewable Energy Target (MRET) that is to provide an additional 9,500 GWh of electricity from renewable sources by 2010. There are three main goals and these are:

- To accelerate the uptake of energy from renewable or specified waste product sources in grid-base applications, so as to reduce greenhouse gas emissions;
- As part of the broad strategic package to stimulate renewables, provide an on-going base for the development of commercially competitive renewable energy; and,
- To contribute to the development of internationally competitive industries that will participate effectively in the burgeoning global energy market.[12]

As this is largely a requirement by the States and Territories, these governments are providing incentives to local energy producers to assist in meeting these targets. Many of these new generators are large producers (such as wind farms and bagasse) but as such are limited to site-specific locations. The Mandatory Renewable Energy Target legislation is currently being reviewed to check to see if it is reducing greenhouse gas emissions and if additional generation has occurred.[13]

The Energy Market Review Panel concluded that “many of the current measures employed to reduce greenhouse gas emissions are poorly targeted. These measures target technologies or fuel types rather than greenhouse gas abatement… The MRET is a more costly measure to reduce greenhouse gas emission that it needs to be as it focuses exclusively on renewable energy sources rather than least cost greenhouse gas abatement, such as reducing energy consumption through providing energy efficiency.”[14]

One contributor to this project observed that instant reductions in energy consumption could be achieved in a large office building merely by changing the lighting systems. Alternatively, planned lower consumption of electricity in personal use is able to provide for even greater reductions through a choice of equipment such as avoiding stand-by power options in consumer electronics and life-style changes.

While the subsidies offered by the Federal Government appear to be substantial, the subsidies are allocated for capital expenditure on renewable energy generation equipment on a month-by-month basis and in some states operate on a lottery system. The rebate from the Goods and Services Tax (GST) does not extend past June 2003 for this equipment and is expected to further dampen sales of photovoltaic systems.[15]

Types Of Renewable Energy Sources

There are a number of types of renewable energy sources. These can possibly be divided into two types - carbon dioxide emission technologies and non-emission technologies. These are shown in Table 12.2 – Renewable Energy Sources. The Electric Power Research Institute noted that while there are many renewable energy sources, the technologies expected to be refined and developed further are wind, photovoltaics and geothermal where appropriate.[16] It is the first two that we will investigate in this report.

Table 12.2 – Renewable Energy Sources

CO2 Emissions	Non-Emission
Sugar mill cogeneration	Wind
Rural Plant waste	Hydro
Land fill gas	Solar hot water
Biomass	Hot dry rocks
	Photovoltaics
	Tidal

Wind

Advancements in this technology have seen wind farms reach levels of electricity generation that rival coal-fired power stations. This technology is the most widely adopted through out the world with some 10 GW installed worldwide. Small, single site wind generators have been installed for some time with larger grid-connected installations coming into NSW in the late 1990s. In 2001, Pacific Hydro installed an 18 MW site at Codrington, Victoria and Wester Power installed at 22 MW site near Albany, Western Australia.

The southern portion of Australia is best suited for wind generation locations and especially near the coast. The installed generating capacity in 2002 was 104 MW with 736 MW in construction[17] and 2,085 MW being proposed.[18] The variability in wind speed is critical to the placement of wind turbines for economic viability. An average wind speed of 7 metres per second must be achieved. At this speed, the generating capacity would provide an owner of conventional equipment with an income of around $75MWh. Slower winds speeds increase the cost of generation and faster winds speeds provide for greater profits.[19]

Most of the international manufacturers of wind turbines are providing turbines with advanced designs that include an active blade pitch control that adjusts the blades to the best angle of attack.[20] The term angle of attack refers to the amount of surface that is exposed to the force of the wind. By being able to control the position of the blades relative to the wind strength, greater efficiencies can be made.

Most wind turbines have the blades positioned up-wind from the tower. As the speed of the wind increases, the blades are bent back. This presents a difficulty and requires the blades to be more sturdy including the tower. This type of design increases the cost of the equipment. An alternative design is to have the blades positioned down-wind of the tower and to hinge the blades. This achieves two goals. The first is that as the blades bend down-wind from the tower, they do not need to be as rigid as blades up-wind. The second goal is that the blades are hinged so that when there is a gale blowing, the hinge releases the vertical orientation and is able to shed excessive loads.[21]

The company with this design, the Wind Turbine Company, believes that this design will lead to a decrease in the cost of wind generation. The cost of the construction of the tower and turbine is 20 to 25 per cent less due to less materials used. The Wind Turbine Company estimates that the cost of generation would be around US3.5 cents kWh (equivalent to AUD$58MWh).[22]

Obviously, if the cost of construction of wind turbines in decreased, the location of these next generation turbines will increase the profitability of premium wind sites and extend the possible area for wind generation further inland. Australia appears to be a favoured location for the manufacture of wind turbines with one of the largest manufacturers, Vestas, establishing a manufacturing facility here.

Wind turbines require a higher maintenance levels than photovoltaic systems and growth in employment is expected in this area as well as in manufacturing.[23] This presents problems for remote areas when maintenance technicians need to attend to breakdowns. Despite this, wind energy is likely to be one of the more successful forms of grid-connected renewable energy generation in Australia.[24]

Photovoltaics

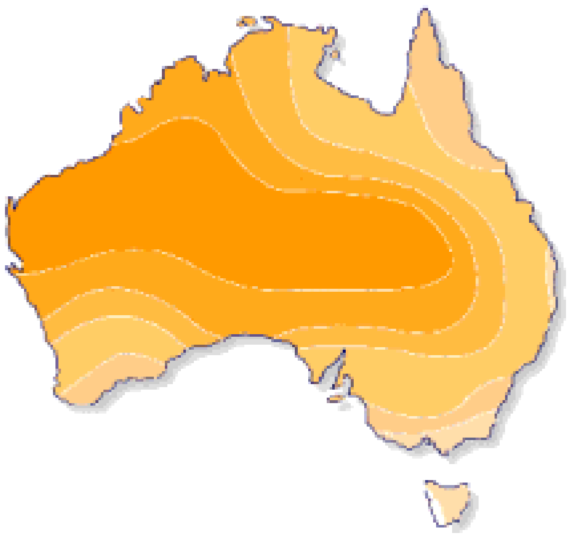
This technology promises to be one of the most interesting and dynamic of all the renewable energy generation methods. Unlike wind and hydro that are primarily based upon physical forces, the conversion of light into electricity has seen a number of different approaches towards generating electricity from sunlight. Current efficiencies are around 18 per cent[25] with some systems operating at 24 per cent efficiency.

Currently, electricity generated from photovoltaics is still very expensive. Commercial roof-top systems for the domestic market provide power at around $16,000 for a 1.2 kW system.[26] Other systems are able to run at around $500/KWh but this is still ten-times the price of coal-fired electricity.[27] Despite this comparatively high cost, photovoltaics will continue to play a role in providing an energy in premium, remote and non-grid connected locations.

Australia has high levels of sun light availability (See Figure 12.1 – Solar Energy Map) and a relatively sparse grid availability for its land mass. These two factors have enabled Australia to become one of the largest users of photovoltaics on a per capita basis. More recently Japan and parts of Europe have surpassed Australia in the use of this technology but this has been largely due to subsidies in these regions.[28] The increased adoption of photovoltaics will be assisted with lower pricing for panels as a result of high-volume manufacturing facilities and the interoperability of equipment.[29]

The technology really requires major advances to improve both its efficiency and lower costs of production. Without these hoped advancements, solar power is likely to supply only 2 per cent of the world's power by 2030.[30] There is tremendous activity in the area of research with a number of Australian universities receiving funding to pursue this goal of reduced cost and improved efficiency. The University of New South Wales has funding until 2009 and is pursuing the goals of thin film, higher efficiency, and inexpensive and non-toxic materials[31] as is the Australian National University Centre for Sustainable Energy Systems.[32]

Figure 12.1 – Solar Energy Map



The darker colour indicates greater amounts of solar energy are available. Solar Map courtesy of the Australian New Zealand Solar Energy Society. Reprinted with permission.

In the manufacture of conventional solar panels around half of the cost is the silicon wafer and the other half is the processing of the wafers and the electrical interconnections. This method of production provides for a non-toxic and stable performance. Greater cost reductions can be obtained by using a process of growing a thin layer of silicon on a conventional wafer. This uses less material and therefore reduces cost. A $1m plant is being constructed by Origin Energy to commercialise this process.[33]

However this thin-film process has suffered some set-backs with the closure of BP Solar's California plant that was producing solar cells from cadmium telluride and amorphous silicon. The efficiencies from these cells did not reach more than around 9 per cent.[34] Other technologies used include heavy metals such as copper indium, gallium selenide, and titanium dioxide. Further work is being done to increase the amount of the solar spectrum used by combining these metals in layers.[35]

Additionally, technology relating to other materials having the ability to convert sunlight into electricity are being researched. One technology uses thousands of tiny silicon spheres, bonded between thin flexible aluminum foil substrates to form solar cells, which are then assembled into durable, lightweight modules that can be applied to virtually any surface.[36] This means that the material can be used to cover buildings and other surfaces to collect energy from sunlight. Other materials are being researched that are able to capture the waste heat from electrical appliances.[37]

Photovoltaic Systems

The solar panels containing the silicon wafers are connected to power conditioning units and protection devices that provide an interface to the local user or the grid. These devices are usually referred to as the "balance of system". The PV system can be a building-integrated photovoltaic system (BIPV) and can be flat panels, tracking panels or integrated into the walls of the building. Centralised systems can be thought of as solar power generation sites where there is no combination of solar collection and building occupancy. Centralised systems can be customised for each particular site and use a variety of technologies.[38]

The most economic use of photovoltaics will be in remote area power supply (RAPS) locations. These supply systems contain a range of generation and storage technologies that use renewable and fossil-fuels. This is a well established industry with further expansion predicted especially with the proposal to have electricity prices include the cost of transmission losses.[39] However, the full market potential is limited by the need to have robust equipment, availability of trained technicians and education of the user for maintenance of the technology.[40]

Power Electronics

This area of technology is rapidly expanding as distributed generation applications become more integrated with grid-based systems. The next generation of power electronics will be more sophisticated than current power conditioning technologies. The Institute of Electrical and Electronic Engineers (IEEE) defines power electronics as a technology that uses "electronic components, the application of circuit theory and design techniques, and the development of analytical tools toward efficient electronic conversion, control and conditioning of electric power."[41]

This area of power electronics is very interesting in terms of its profile and perceived importance. During the consultation process with industry participants, those individuals who were closer to the newer technologies and the implementation of such systems showed more interest in power electronics. For individuals further removed from the leading edges, power electronics was viewed as an area that did not have much scope for further improvement or advances.

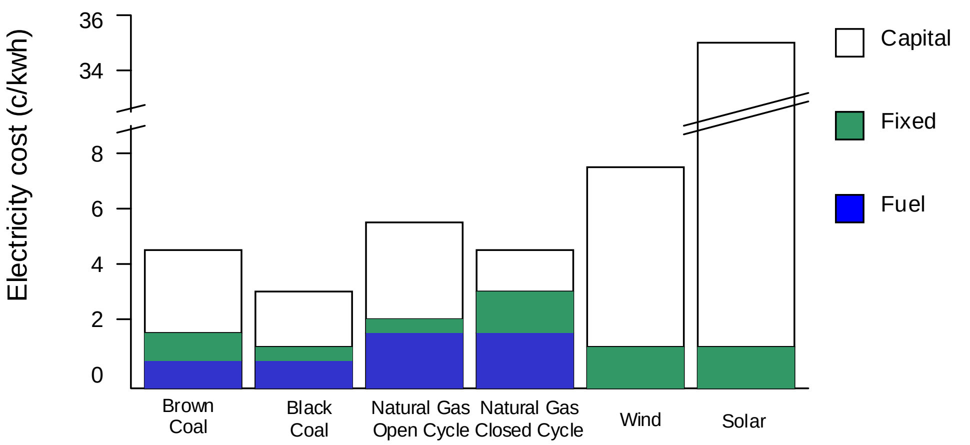
Advances in power electronics are likely to have a significant part in the increasing integration of power systems especially within direct current systems and direct current and alternating current connections. The use of lower voltages for microprocessors is driving research.[42] The new range of motor vehicles using a hybrid engine system use various strategies to achieve the best efficiency. The use of power electronics in motor drive controls is likely to increase. This is especially the case for variable speed transmissions that are to be used in automobiles as well as in wind turbines.[43]

Summary

The adoption of renewable energy sources discussed here will depend to a greater or lesser extent on the subsidy arrangements provided by government agencies. In some locations, users will select these technologies mentioned here regardless of subsidy arrangements as the non-renewable alternatives will be more expensive.

For wind turbines, the cost of manufacture is declining and efficiency is improving as a result of mass markets and research. Photovoltaics is suffering from comparatively low efficiencies and difficulties in manufacturing however research is continuing to evolve new methods of manufacture. See Figure 12.2 for a summary of the costs for each energy type.

Figure 12.2 – Fuel and Capital Costs for Electricity Production



From COAG (2002) Draft Energy Review Report, Figure 8.3: Estimated Electricity Generation Costs - Inclusive of Capital Costs

IMPLICATIONS FOR THE SHARED TECHNOLOGY INDUSTRIES

Automotive

Limited application for this industry in wind and solar energy. Power electronics are likely to become more prominent in automotive electronics.

Building and Construction

New and innovative uses of materials and building design will see an increase in the use of renewable energy systems. The retro-fitting of these technologies and others such as water collection, conservation and treatment to existing buildings will require new skills. Closer integration with electrical technicians will also be required.

Electrical

This industry will be affected by the increase in the numbers of individuals involved in installing and maintaining these systems. Power electronics will become more important in the design and construction of renewable energy systems.

Electronics

As many of these systems will be driven by the electronics and the number of sites expected to increase, there will be a need for more individuals with diagnostic skills to be involved in this area. Power electronics will play an important role in the management of these systems.

Engineering

Remote Area Power Systems are likely to increase requiring the development of more reliable systems. This will require improved reporting and control systems through remote access monitoring. Additionally the increase in the use of advanced power electronics systems will require technicians from this area to develop additional skills and knowledge in relation to this technology.

Information technology

Management systems for remote monitoring of renewable energy sites will be an important part of maintenance and efficient energy production systems. Software programs and web-based applications will need to be written to for ease of management by low-skilled users of these systems through to larger, commercial generators.

Telecommunications

Remote monitoring systems will need to be devised to allow for efficient operation. This may require the use of satellite communications or other methods to connect to the generation sites.

[1] Williams, A. (2002). *Energy and transport sector: Outlook to 2020*. p. 26. North Ryde, NSW: CSIRO. Available: http://www.det.csiro.au/PDFfiles/EnergyTransportSectorOutlook2020.pdf Accessed: 22 March, 2003.

[2] Parer, W. R. (2002). *Towards a truly national and efficient energy market*. Canberra: Commonwealth of Australia. Available: http://www.energymarketreview.org/FinalReport20December2002.pdf Accessed: 22 March, 2003.

[3] Williams, A. (2002). *Energy and transport sector: Outlook to 2020*. p. 12. North Ryde, NSW: CSIRO. Available: http://www.det.csiro.au/PDFfiles/EnergyTransportSectorOutlook2020.pdf Accessed: 22 March, 2003.

[4] Redding, G. (2002). *Where is renewable energy going in Australia?: ESAA 8th renewable and sustainable power conference.* Armadale, VIC: Sinclair Knight Merz. Available: http://www.skmconsulting.com/index.cfm?id=1458 Accessed: 22 March, 2003.

[5] Electricity Supply Association of Australia Limited. (2002). *Domestic electricity prices 2002/2003* and *Business electricity prices 2002/2003*. Sydney, NSW: Author.

[6] Australian Greenhouse Office. (2002). *National greenhouse gas inventory: Analysis of trends and greenhouse indicators 1990 to 2000*. Canberra: Author. Available: http://www.greenhouse.gov.au/inventory/2000/trends Accessed: 22 March 2003.

[7] Kemp, D. (2003). *Australia's approach to climate change*. Opening address Beyond Kyoto. Institute of Public Affairs. Melbourne. Available: http://www.ea.gov.au/minister/env/2003/sp28feb03.html Accessed: 28 March 2003.

[8] Electricity Supply Association of Australia Generation Directorate. (2002). *Impact of a carbon cost on Australia's electricity generation*. Melbourne: Electricity Supply Association of Australia.

[9] Kemp, D., & MacFarlane, I. (2003). *Million dollar boost to renewable energy industry*. Joint media release 25 March, 2003. Canberra: Department for the Environment and Heritage and the Department for Industry, Tourism and Resources. Available: http://www.ea.gov.au/minister/env/2003/mr25mar203.html Accessed: 28 March, 2003.

[10] Australian Greenhouse Office. (2000). *Climate change a national commitment: Greenhouse gas abatement program*. Canberra: Author.

[11] Department of Industry, Science and Resources. (2000). *New era new energy: Renewable energy action agenda*. Canberra: Commonwealth of Australia. Available: http://www.isr.gov.au/content/controlfiles/display_detailscfm?objectid=D5DAC0BC-6D49-4CC3-9A6AED012142802F Accessed: 14 November, 2002.

[12] Department of Industry, Tourism and Resources. (2002). *Renewable energy technology roadmap*. p. 17. Canberra: Commonwealth of Australia. Available: http://www.industry.gov.au/retr Accessed: 14 November, 2002.

[13] Kemp, D., & MacFarlane, I. (2003). *MRET review panel announced*. Joint media release 25 March, 2003. Canberra: Department for the Environment and Heritage and the Department for Industry, Tourism and Resources. Available: http://www.ea.gov.au/minister/env/2003/mr25mar203.html Accessed: 28 March, 2003.

[14] Parer, W. (2002). *Towards a truly national and efficient energy market*. p. 230. Canberra: Commonwealth of Australia. Available: http://www.energymarketreview.org/FinalReport20December2002.pdf Accessed: 22 March 2003.

[15] Lowe, I. (2003). Clouding future energy. *New Scientist*, p. 59. 8 March, 2003.

[16] Electric Power Research Institute. (1999). *Electricity technology roadmap initiative.* pp. 78-79. Palo Alto, CA: Author. Available: http://www.epri.com/corporate/discover_epri/roadmap/index.asp Accessed 1 January, 2003.

[17] Passey, R. (2003). *Driving investment, generating jobs: Wind energy as a powerhouse for rural & regional development in Australia*. Melbourne: Australian Wind Energy Association. Available: http://www.auswea.com.au/downloads/passeyjobsreport.20.3.2003.pdf Accessed: 11 April 2003.

[18] Redding, G. (2002). *Where is renewable energy going in Australia?: ESAA 8th renewable and sustainable power conference.* Armadale, VIC: Sinclair Knight Merz. Available: http://www.skmconsulting.com/index.cfm?id=1458 Accessed: 22 March, 2003.

[19] Redding, G. (2002). *Where is renewable energy going in Australia?: ESAA 8th renewable and sustainable power conference.* Armadale, VIC: Sinclair Knight Merz. Available: http://www.skmconsulting.com/index.cfm?id=1458 Accessed: 22 March, 2003.

[20] Outhred, H. (2003). *Wind energy and the national electricity market with particular reference to South Australia*. Canberra: Australian Greenhouse Office. Available: http://www.ergo.ee.unsw.edu.au/papers/AGO_SA_Wind_Energy.pdf Accessed: 22 April, 2003

[21] Fairley, P. (2002). Wind power for pennies. *Technology Review*, *105*, (6), pp. 40-46. July-August, 2002.

[22] Economist. (2003). Turnaround for wind power. *Economist*, 13 March, 2003. Available: http://www.economist.com/science/tq/displayStory.cfm?story_id=1620762 Accessed: 10 April 2003.

[23] Passey, R. (2003). *Driving investment, generating jobs: Wind energy as a powerhouse for rural & regional development in Australia*. Melbourne: Australian Wind Energy Association. Available: http://www.auswea.com.au/downloads/passeyjobsreport.20.3.2003.pdf Accessed: 11 April 2003.

[24] Department of Industry, Tourism and Resources. (2002). *Renewable Energy Technology Roadmap*. Canberra: Commonwealth of Australia. Available: http://www.industry.gov.au/retr Accessed: 10 April 2003.

[25] Department of Industry, Tourism and Resources. (2002). *Renewable energy technology roadmap*. p. 64. Canberra: Commonwealth of Australia. Available: http://www.industry.gov.au/retr Accessed: 14 November, 2002.

[26] See Pacific Solar. http://www.pacsolar.com

[27] Williams, A. (2002). *Energy and transport sector: Outlook to 2020*. p. 27. North Ryde, NSW: CSIRO. Available: http://www.det.csiro.au/PDFfiles/EnergyTransportSectorOutlook2020.pdf Accessed: 22 March, 2003.

[28] Green, M. A. (2002). *Australian photovotaic research and development*. Sydney: University of New South Wales. Available: www.pv.unsw.edu.au/29thIEEE/MAG_Aust.pdf Accessed: 11 April 2003.

[29] National Renewable Energy Laboratory. (2001). *Solar-electric power: the U.S. photovoltaic industry roadmap*. Washington, DC: U.S. Department of Energy. Available: http://www.nrel.gov/ncpv/pvplans.html Accessed: 11 April 2003.

[30] Electric Power Research Institute. (1999). *Electricity technology roadmap initiative.* p. 83. Palo Alto, CA: Author. Available: http://www.epri.com/corporate/discover_epri/roadmap/index.asp Accessed 1 January, 2003.

[31] Green, M. A. (2002). *Australian photovotaic research and development*. Sydney: University of New South Wales. Available: www.pv.unsw.edu.au/29thIEEE/MAG_Aust.pdf Accessed: 11 April 2003.

[32] Blakers, A. W. (2001). *Solar energy research at the Australian National University*. Canberra: Australian National University. Available: http://solar.anu.edu.au/Pages/pdfs/SolarEnergyResearchANU200.pdf Accessed: 11 April 2003.

[33] Blakers, A. W. (2001). *Solar energy research at the Australian National University*. Canberra: Australian National University. Available: http://solar.anu.edu.au/Pages/pdfs/SolarEnergyResearchANU200.pdf Accessed: 11 April 2003.

[34] Fairley, P. (2003). BP Solar ditches thin-film photovoltaics. *IEEE Spectrum*, January 2003. p. 18.

[35] Hogan, J. (2002). Now we can soak up the rainbow. *New Scientist*, 7 December, 2002, p. 24.

[36] Hogan, J. (2003). Denim buildings are latest in green chic. *New Scientist*, 15 February, 2003, p. 19. Also see Spheral Solar Available: http://www.spheralsolar.com/2_spheral-technology Accessed: 11 April 2003.

[37] Ananthaswamy, A. (2003). Not quite nano, but its hot. *New Scientist*, 22 February, 2003, p. 22.

[38] Department of Industry, Tourism and Resources. (2002). *Renewable energy technology roadmap.* p. 64-65. Canberra: Commonwealth of Australia. Available: http://www.industry.gov.au/retr Accessed: 14 November, 2002.

[39] Parer, W. R. (2002). *Towards a truly national and efficient energy market*. Canberra: Commonwealth of Australia. Available: http://www.energymarketreview.org/FinalReport20December2002.pdf Accessed: 22 March, 2003.

[40] Department of Industry, Tourism and Resources. (2002). *Renewable energy technology roadmap.* p. 75. Canberra: Commonwealth of Australia. Available: http://www.industry.gov.au/retr Accessed: 14 November, 2002.

[41] Institute of Electrical and Electronic Engineers. (2003). *About the IEEE power electronics society*. Available: http://www.pels.org/AboutPELS/AboutPELS.html Accessed: 11 April 2003.

[42] Institute of Electrical and Electronic Engineers. (2003). *About the IEEE power electronics society*. Available: http://www.pels.org/AboutPELS/Applications/computers.html Accessed: 11 April 2003.

[43] Institute of Electrical and Electronic Engineers. (2003). *About the IEEE power electronics society*. Available: http://www.pels.org/AboutPELS/Areas/motors.html Accessed: 11 April 2003.