10 - Electricity Production and Distributed Generation

The use and availability of electricity will be a major determinant of communication, finance and economic growth for Australia. The provision of reliable and low-cost electricity will be instrumental for Australia's future economic growth with internationally competitively priced energy services.[1]

The Australian Bureau of Agriculture and Resource Economics (ABARE) has linked economic growth to Australia's projected increase in energy consumption. ABARE estimates that the growth in Australia's Gross Domestic Product (GDP) to be around 3.5 per cent per annum until 2020. This growth rate is expected to see an annual increase in total energy consumption at 2 percent per annum.[2] This means that Australia will consume 50 per cent more energy in 17 years time than it does now. This also means that new investment will be required to meet this demand.

Fortunately, Australia is able to met this need with existing primary energy resources for many years to come. Australia has approximately 800 years of brown coal, 290 years of black coal and around 100 years supply of natural gas[3] with exploration continuing.[4] Over the next two decades, electricity generation is expected to increase 2.3 per cent per annum to 325 terrawatt hours by 2020. Black coal is expected to be the primary energy source providing 170 terrawatt hours. Natural gas is expected to grow by 4.9 per cent per annum and will account for around 31 per cent of the total increase.[5]

he investments required to meet this demand will be 7,000 MW of new generation costing around $10 billion to 2010. Additionally, new investment in high voltage transmission and distribution networks will also be needed costing around $5.3 billion to 2008.[6] The natural gas pipeline infrastructure will also need to be expanded to meet this expected demand even though gas remains at a price disadvantage to black and brown coal.[7]

This increase in demand for electricity will have an impact on the group of industries covered in this Shared Technology Project. At first glance, the impact of this growth may not appear to be directly related to any industry other than electricity generation and perhaps the electrical industry. However as will be demonstrated in this section of the report, the provision of and use of increasing demand for electricity will have some impact on the Shared Technology Industries.

Current Issues

A recent report commissioned by the Department of Industry Tourism and Resources, *Towards a Truly National and Efficient Energy Market*, highlights many important aspects of electricity generation, transmission and distribution. One of these issues is the regulation of electricity throughout the eastern states of Australia. A number of recommendations have been identified in this energy market review but are not central to this project. However there are two recommendations that do have some interest to this Shared Technology Project.

One issue is that the cost of transmission is averaged across all users and therefore sets pricing that does not reflect the true cost of transmission. Queensland Treasury suggests that network charges can represent between 60 and 80 percent of the total delivered electricity costs for most rural and regional users in Queensland, and represents over 80 percent of total charges for regional users in far North Queensland.[8]

The continuation of subsidies is likely to undermine incentive for efficient use and development of transmission networks, and possibly preclude otherwise efficient alternatives, such as Remote Area Power Systems (RAPS) and distributed generation.

The other issue is the diurnal homogeneity of pricing for electricity. The cost of electricity is averaged over the day so that the consumer has little incentive to adjust consumption patterns. That is, even though power usage across the network may be in high demand, the price remains the same per kilowatt hour as it does during non-peak periods. Because of this fixed pricing, generators are required to have more capacity than may necessarily be required. Additionally, the Electricity Supply Association of Australia has stated that a key challenge for the Australian electricity supply industry is the management of peak power demand which is growing at almost double the average load. This is primarily attributed to air cooling applications such as air conditioning.[9]

The Energy Market Review Panel has recommended that electricity meters be installed that charge the consumer the real-time cost for the electricity being consumed. The consumer would be aware of peak-period pricing and adjust electricity use during those periods. This move to install meters would require a roll-out period of around five years and would mean fitting residences and small business with these interval meters.[10]

Electricity Prices and Gross Domestic Product

The Electricity Supply Association of Australia (ESAA) states that Australian electricity prices are among the lowest in the world with residential as seventh lowest and industrial as third lowest.[11] The residential market currently represents 27 per cent of total electricity consumption in Australia with the average annual growth in this market is expected to be 2.3 per cent between 2001 and 2020.[12] Business and industrial use of electricity represents around 70 percent with aluminum smelting comprising 30 per cent of total use. Business and industrial use of electricity is expected to grow at 2.6 per cent to 2020.[13]

Over the past thirty years, the total use of energy has risen but the growth in demand is slowing from 6 per cent per annum in the mid 1960's to just 1.4 per cent in 2000-2001.[14] Energy consumption closely follows trends in Australian Gross Domestic Product (GDP) and the total growth in energy is thereby estimated at 2 per cent per annum with a GDP of 3.5 per cent per annum forecast for the next two decades.[15]

Due to the use of information and communication technologies (ICT), an increase in productivity may not necessarily result in higher consumption of energy.[16] The increased use of ICT requires a more reliable power supply. The cost of power outages in the United States is estimated, for example, to be US$6.5m per hour within a on-line share brokerage agency. Even with a reliability rate of 99.99 per cent, this amounts to 53 minutes of power outages per year.[17] Therefore reliability rates of "nine-nines" or 99.9999999 per cent are being sought.

Implications for Electricity Use

What may be able to be demonstrated from the above is that growth in the economy is dependent upon energy use and new investment will be required to meet the predicted growth. Additionally, the electricity market is set to become less regulated and more competitive. This decrease in regulation will see the price of peak-demand electricity charged directly to the user and not averaged over the entire day. Real-time pricing of electricity will see changes in consumption patterns by consumers and businesses, changes in the technology used and increases in generation capacity that is more consumer controlled and closer to the user.

Technology

The Electric Power Research Institute (EPRI) has developed overviews of technology innovation and advancements for the past 25 years.[18] The EPRI links electricity-based innovation as the primary driver for economic growth and cites four main change processes that are likely to accelerate. These are:

- The opportunities for efficient conversion to electricity move closer and closer to the customer;
- Power electronics usher in a new age of precision delivery of power;
- Electrotechnologies boost industrial and service sector productivity to new heights with greater energy efficiency and reduced environmental impact; and,

- Information technology redefines the boundaries and relationships between producers and customer, creating near-frictionless markets.[19]

Underlying issues for technological innovation and adoption.

There are a number of challenges facing the electricity supply industry. These relate to air quality, greenhouse gas emissions, fuel type, sustainable development, demand management, accessibility, affordability, and reliability of supply. A discussion of each of these issues just mentioned is beyond the scope of this project as the issues relate to community-based priorities and the decision to use a particular technology is based upon these community preferences. It is not the goal of this project to recommend maximum levels of emissions or consumption of resources as this report is an examination of technology options and should be, as much as possible, value-free.

The Australian Government has chosen not to ratify the Kyoto treaty for a number of reasons (and these are not important in this discussion). While David Kemp, Minister for the Environment and Heritage, noted that technology will play a key role in enabling countries to make a smooth transition to a lower (greenhouse and noxious) emission economy, the drivers of change need to have a minimum cost to industry in terms of capital investment and international competitiveness. However it is important that Australia proactively positions itself to capture major business opportunities by using new and appropriate technology.[20]

Despite the refusal by the Australian Government to ratify the Kyoto treaty, moves by individuals, enterprises and government bodies to reduce consumption patterns, increase efficiencies and reduce emissions are being made. The approach towards the reduction in emissions does need to be made through better targeted programs that do not necessarily focus on renewable energy options.[21] Some of these may be the use of “clean” coal technology which is briefly examined below (See Box 10.1 - Electricity Generation Technologies).

Electricity generation in the Shared Technology Industries

There are a range of devices, processes and options available for the generation of electricity. As this project investigates the shared technologies that will be applied across a defined range of industries, not all energy options will be discussed. The energy options that are discussed are:

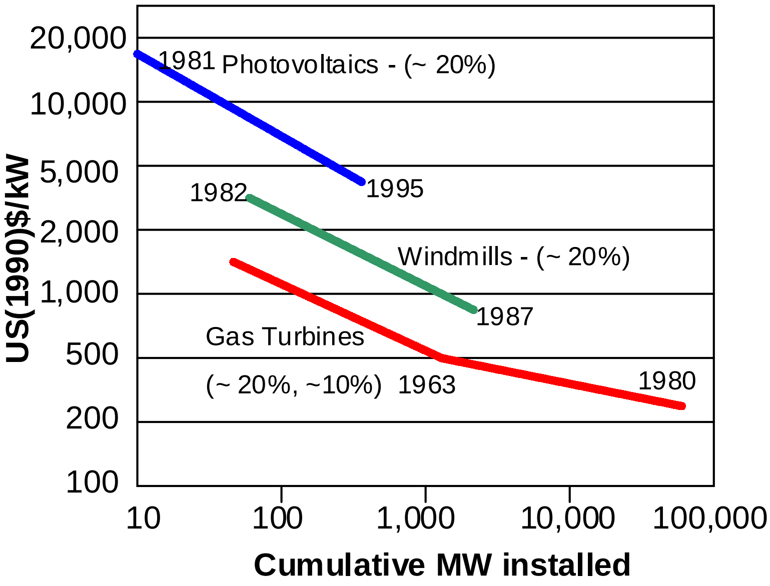
- gas powered generation, co-generation (including gas-fired cooling systems);
- renewable energy; and
- fuel cells.

These technology options are discussed in Chapters 11, 12 and 13 respectively. These options have been chosen as their impact is likely to be felt across the range of industries included in this project.

There seems to be a relationship between the installation of new technologies for generating electricity and the cost of the technology in kilowatts. As a technology becomes more popular, the cost of producing one kilowatt of power also declines. This certainly relies upon increases in production capacity, it also relies upon technological improvements. See Figure 10.1 – Learning Rates for Energy Systems.

While the costs of photovoltaics per kilowatt are higher than wind, the costs of the more expensive overlap the early historical costs of the next less expensive technology. This downward trend shows a 20 per cent learning rate over time. It may be possible to expect that even despite the discovery of new photovoltaic methods this technology may become more economically viable in distributed generation systems.

Figure 10.1 – Learning Rates for Energy Systems.



Three learning curves for electricity generation technologies showing historical reduction of costs with increasing scale of installations for gas turbines, 7windmills and photovoltaics. Adapted from Nackicenovic, N. and Riahi, N., 2002, p. 5. Reproduced with permission.

Distributed Generation

The move to a more "decentralised" stationary energy production capacity has been signalled by many observers. The growth in demand and the range of technologies available will see more electricity generation taking place closer to the user. As a result, this move to power generation closer to the user will impact upon building and construction; electrical, electronics, information technology and telecommunications industries. This will be in the form of allocation of equipment within buildings and management of generating capacity through the other industries just mentioned.

Box 10.1 – Electricity Generation Technologies

Biomass *- This type of energy is derived from plant or animal material such as wood, logging waste or agricultural waste (especially sugar cane fibre). Two main types of technologies exist for this energy source. One is the decomposition of waste through bacterial action which produces methane and carbon dioxide. This can occur in landfill sites or animal husbandry locations and utilises the methane only. The other is the burning of the waste to produce steam.*

Geothermal (hot dry rocks) *- There are a number of methods of extracting heat from the Earth's core but Australia is limited to locations where solid, dry rock is located. In this arrangement, holes are drilled in the rock and water is heated. This heated water is then used to generate steam for standard geothermal power stations.*[22] *Other locations have sites where water is naturally passed through heated rocks and used for steam (for example New Zealand) and this water is used directly.*

Coal gasification *(also known as integrated gasification combined cycle) - This process involves steam, oxygen and coal being brought together at high temperatures (1850 degrees Celsius) to create a thermochemical reaction. This reaction produces a mixture of hydrogen and carbon dioxide. The hydrogen is used either in a gas turbine or fuel cell while the carbon dioxide is sequestered or is allowed to escape into the atmosphere. The waste heat from the gas turbine or fuel cell is used to generate electricity via a steam turbine thereby gaining the name "combined cycle". Increases in efficiencies are expected to nearly double current coal-fired power stations.*

Traditionally, electricity has been generated by large power stations, located close to their fuel source and sometimes a long distance from the main centres of electricity use. In contrast, distributed generation is small and modular, and can be located close to end-users who may be in an industrial area, inside a building or operated by a community organisation. The generated output can be used by the generators themselves or exported to the AC grid directly.[23]

The establishment of distributed generation systems can be as developed as heating, cooling and powering a commercial building using a combination of technologies including solar panels, microturbines, and fuel cells. Alternatively a distributed generation system can use waste materials such as the methane produced by decomposing animal manure.[24]

Regulation of Distributed Generation

For remote areas not connected to an electricity grid, there is no reason to apply an regulatory framework apart from safety issues. However in a networked grid system, issues of quality of supply and competition with the bulk providers of electricity do arise. These issues are viewed as being complex and, until a suitable framework is achieved, development of distributed generation will be limited.[25]

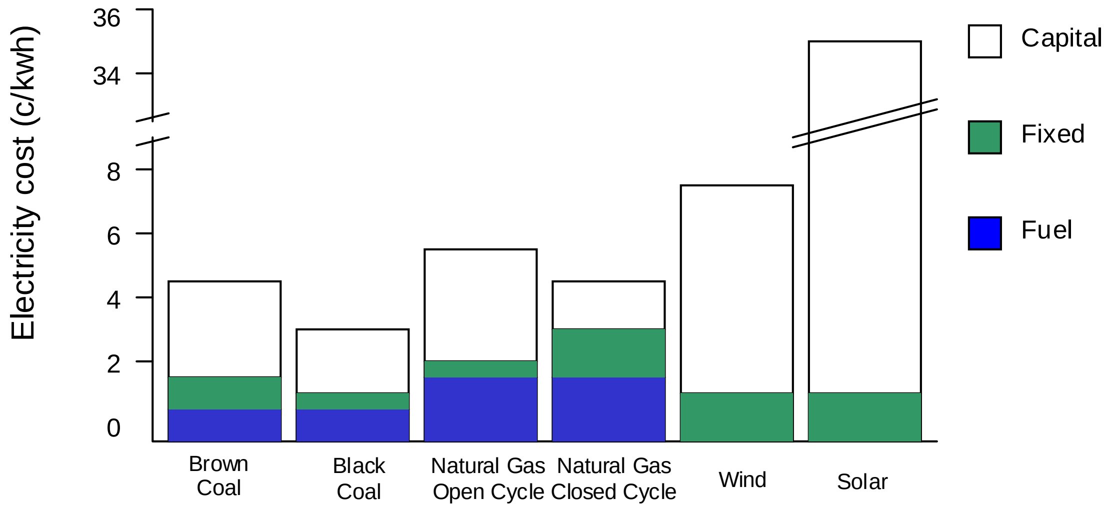
Economics of Distributed Generation

Apart from "premium power" locations where grid connection is not available, distributed generators will need to be able to produce electricity at price levels that equal the lowest cost producer - brown and black coal. In this environment, distributed generators would need to be able to produce power at around $32/kW.

However, other factors work for distributed generation. These are the reliability of user managed power at the site and risk of power outages on revenue. Additionally, there is the expected move to have end-user costs reflect the loss incurred in transmission. As will be shown in the following chapter, when gas-powered microturbines are used in a co-generation configuration, it can lead to a substantial increase in efficiencies.

While not likely to be evident in the time frame set for this project, advances in manufacturing processes are leading to improvements in efficiencies in photovoltaics. This may lead to this energy option providing for an increasing part of energy production. See Figure 10.2 – Estimated Electricity Costs.

Figure 10.2 – Estimated Electricity Costs.



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

Energy Storage

With distributed generation systems in the form of renewable energy systems (such as wind and solar) there is the possibility that these generators may not always be available when power is required. During these times, a back-up supply needs to be able to be brought on-line quickly. If the distributed system is connected to the main electricity grid, then the grid will act as "energy storage". However if this is not available, other systems need to be available.

There are two types of energy storage systems that can provide a role. One is an energy system that provides energy to meet peak demand and is prepared for this planned use. These types of systems often use water or compressed air to provide energy. The other is an energy system that can rapidly meet the demand such as during a power failure and are often battery systems.[26]

<u>Pumped-hydro</u>

A "pumped-hydro" system uses low cost power to pump water up-hill to a storage facility. When peak loads are experienced, the water is allowed through a turbine to generate electricity. This process works in exactly the same way as hydro-power, but the water is reused on a daily basis. With any physical or chemical process, not all the energy stored is able to be captured. In the case of pumped-hydro, the recapture of energy is around 70 per cent efficient.

Compressed air

A compressed air energy storage system also uses electricity during non-peak periods to send air into a terrestrial cavern at high pressure. Unlike the pumped-hydro option, there is no need to store the air as it escapes. Consequently, this high-pressure air can be mixed with a low fuel-to-air ratio in a turbine to generate electricity. The resulting cost of the energy produced is lower than through traditional generation.

Thermal storage

Another method of storing energy is to utilise low-cost power to chill water for release the following day. In this system a large tank of fluid (usually called a phase-change material) is cooled (or heated) during off-peak periods. The cooling equipment needed is sometimes less than for normal systems as it is able to operate at full-load during the night rather than variable loads during the day.[27] These systems have the capacity to reduce costs despite the high capital costs for the infrastructure.

Flow cells

Finally, it is possible to “store” electricity using a combination of two electrolytes within a system known as a flow cell. This is similar to a fuel cell (which is discussed more fully in Chapter 13) as the electrolytes passing through a catalyst membrane release an electron. This release provides for a direct current to be passed. However the electrolyte needs to be recharged where as the fuel cell gains its energy source from another material, commonly hydrogen.

The flow cell is recharged from the power grid during off-peak periods and is used as the other energy storage systems mentioned above for peak periods. There are two main types currently in use. One uses a sodium-based electrolyte[28] and another (developed at the University of New South Wales) uses vanadium.[29]

Summary

This chapter has not investigated the shared technologies themselves but more of the issues that surround the likely adoption and use of these technologies. While the technology itself may be “value-free”, the choices that individuals, enterprises and government bodies make are not. There will also be differing priorities for each of these groups.

The technologies that will be used to generate electricity must be able to demonstrate cost efficiencies based upon the costing formulae that are accepted by the community. That is, if greenhouse gas emissions and air quality are to be included then technologies such as traditional coal-fired power generators are likely to be less favoured.

Australia’s industry, especially metal smelting, must compete internationally and this requires low electricity costs. Australian enterprises require a reliable power supply and this provides distributed generators with a growing market with a range of solutions available.

Implications for the Shared Technology industries

Automotive

As electricity generation is stationary, there is little impact for this industry from this technology.

Building and Construction

Distributed generation will require buildings to be more integrated with power systems including storage tanks for thermal energy. While primarily a construction issue with other technicians installing generation equipment, issues relating to correct site preparation and safety will become increasingly important.

Electrical

The expected increase in distributed generation will require the development of skills to install, commission and maintain this new capacity. Operatives will need to ensure that optimum levels of efficiency are being met through advanced control and monitoring systems.

The installation of meters for the purpose of variable-rate billing will become an issue with more of these devices being installed.

Electronics

Monitoring and control systems will need to be designed that provide for remote administration of these systems. Power electronics will become more instrumental in the development of reliable, real-time network control. Additionally reliability issues and power conditioning for network-connected computing equipment will become more important.

Information Technology

The move to a more integrated network for the electricity grid will see further work being carried for Supervisory Control and Data Acquisition (SCADA) systems including bidding and billing systems. The existing grid needs to be transformed into an electronically controlled smart electricity network in order to handle the escalating demands of these new competitive markets in terms of scale, transactional complexity and power quality.[30]

Telecommunications

Distributed generation systems will rely upon real-time networks reporting data critical to the maintenance of this infrastructure. Additionally, some technologies may require intervention but be geographically removed from a skilled workforce. Therefore robust and reliable communication systems are required to ensure remote access to these sites.

[1] Dickson, A., Short, C., Donaldson, K., & Roberts, A. (2002). Australian energy: Key issues and outlook to 2019-2020. *Australian Commodities*, *9*, pp. 198-208. Available: http://abareonlineship.com/product.asp?prodid=12315 Accessed: 22 March, 2003.

[2] Dickson, A., Thorpe, S., Harman, J., Donaldson, K., & Tedesco, L. (2001). *Australia's energy outlook to 2019-2020*. Canberra: Australian Bureau of Agriculture and Resource Economics. Available: http://abareonlineship.com/product.asp?prodid=12235 Accessed: 22 March, 2003.

[3] 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.

[4] Exxon makes huge gas discovery. 24 March, 2003. CNN.com

[5] Dickson, A., Thorpe, S., Harman, J., Donaldson, K., & Tedesco, L. (2001). *Australia's energy outlook to 2019-2020*. Canberra: Australian Bureau of Agriculture and Resource Economics. Available: http://abareonlineship.com/product.asp?prodid=12235 Accessed: 22 March, 2003.

[6] Electricity Supply Association of Australia Limited. (2002). *Australian electricity supply development 2000-2002*. p. 11. Sydney: Author.

[7] Parer, W. R. (2002). *Towards a truly national and efficient energy market*. p. 185. Canberra: Commonwealth of Australia. Available: http://www.energymarketreview.org/FinalReport20December2002.pdf Accessed: 22 March, 2003.

[8] Parer, W. R. (2002). *Towards a truly national and efficient energy market*. p. 132. Canberra: Commonwealth of Australia. Available: http://www.energymarketreview.org/FinalReport20December2002.pdf Accessed: 22 March, 2003.

[9] Electricity Supply Association of Australia Limited. (2002). *Australian electricity supply development 2000-2002*. p. 15. Sydney: Author.

[10] Parer, W. R. (2002). *Towards a truly national and efficient energy market*. pp. 180-181. Canberra: Commonwealth of Australia. Available: http://www.energymarketreview.org/FinalReport20December2002.pdf Accessed: 22 March, 2003.

[11] Electricity Supply Association of Australia Limited. (2002). *Australian electricity supply development 2000-2002*. Sydney: Author.

[12] Electricity Supply Association of Australia Limited (2002). *Electricity sales forecasts by state and class to 2020*. p. 14. Sydney: Author. Available: http://www.esaa.com.au/images/Projections_to_2020_April_2002.pdf Accessed: 3 April 2003.

[13] Electricity Supply Association of Australia Limited (2002). *Electricity sales forecasts by state and class to 2020*. p. 15. Sydney: Author. Available: http://www.esaa.com.au/images/Projections_to_2020_April_2002.pdf Accessed: 3 April 2003.

[14] Australian Bureau of Agricultural and Resource Economics. (2002). *Energy update: Australian energy consumption and production, 1973-74 to 2000-01*. Canberra: Author. Available: http://www.abareonlineship.com/product.asp?prodid=12442 Accessed: 22 March, 2003.

[15] Australian Bureau of Agricultural and Resource Economics. (2001) *Australian Energy: Projections to 2019-20*. Canberra: Author. Available: http://abareonlineshop.com/product.asp?prodid=12196 Accessed: 3 April 2003.

[16] Australian Bureau of Agricultural and Resource Economics. (2001) The 'new economy' and the energy sector: Assessing the economic impacts. *ABARE Current Issues, June 2001*. Available: www.abare.gov.au/htdocs/pages/freepubs/2energy.pdf Accessed: 3 April 2003.

[17] Vassallo, T. (2002). *Energy storage in distributed generation*. North Ryde, NSW: CSIRO. Available: http://www.cendep.csiro.au/html/seminars.htm Accessed: 22 March, 2003.

[18] Electric Power Research Institute (1999). *Electricity technology roadmap initiative*. Palo Alto, CA: Author. Available: http://www.epri.com/corporate/discover_epri/roadmap/index.asp Accessed: 3 April 2003.

[19] Electric Power Research Institute (1999). *Electricity technology roadmap initiative*: *Executive summary*. Palo Alto, CA: Author. Available: http://www.epri.com/corporate/discover_epri/roadmap/index.asp Accessed: 3 April 2003.

[20] Kemp, D. (2003). *Australia's approach to climate change: Opening address to beyond Kyoto: Economic impacts and alternative mitigation strategies conference*. Melbourne: Institute of Public Affairs. Available: http://www.ea.gov.au/minister/env/2003/sp28feb03.html Accessed 28 March, 2003.

[21] Parer, W. R. (2002). *Towards a truly national and efficient energy market*. pp. 180-181. Canberra: Commonwealth of Australia. Available: http://www.energymarketreview.org/FinalReport20December2002.pdf Accessed: 22 March, 2003.

[22] See Geodynamics Limited. Available: http://www.geodynamics.com.au Also see the Cooperative Research Centre for Mining Technology and Equipment - Tight Radius Drilling Available: http://www.cmte.org.au/research/trd.html

[23] Parry, T. G. (2002). *Distributed generation : Discussion paper No. 52*. p. 1. Sydney: Independent Pricing and Regulatory Tribunal of New South Wales. Available: http://www.ipart.nsw.gov.au/pdf/dp52.pdf Accessed: 22 March, 2003.

[24] Vassallo, T. (2002). *A radical new way of looking at energy and power*. North Ryde, NSW: CSIRO. Available: http://www.cendep.csiro.au Accessed 10 January, 2003.

[25] Parer, W. R. (2002). *Towards a truly national and efficient energy market*. p. 82. Canberra: Commonwealth of Australia. Available: http://www.energymarketreview.org/FinalReport20December2002.pdf Accessed: 22 March, 2003.

[26] Office of Energy. (2001). *Energy storage*. Brisbane: Queensland Treasury. Available: http://www.energy.qld.gov.au/electricity/infosite/information_sheets/energy_storage/info_sheet/energy_storage.htm Accessed: 4 April 2003.

[27] American Society of Heating, Refrigerating and Air-Conditioning Engineers. (1994). *Thermal energy storage strategies for commercial HVAC systems*. Atlanta, GA: Author. Available: www.pge.com/003_save_energy/003c_edu_train/pec/info_resource/pdf/THRMSTOR.PDF Accessed: 4 April 2003.

[28] See Regenesys Technologies. Available: http://www.regenesys.com Accessed: 22 April, 2003. Also see Fairley, P. (2003). Recharging the power grid. *Technology Review*, March 2003, pp. 52-56.

[29] Skyllas-Kazacos, M. (2001). *An historical overview of the vanadium redox flow battery development at the University of New South Wales, Australia.* Sydney: University of New South Wales. Available: http://www.ceic.unsw.edu.au/centers/vrb/overview.htm Accessed: 22 April, 2003.

[30] Electric Power Research Institute (1999). *Electricity technology roadmap initiative.* p. 4. Palo Alto, CA: Author. Available: http://www.epri.com/corporate/discover_epri/roadmap/index.asp Accessed: 3 April 2003.