Final Report for a Fuel Cell Installed with the Assistance of the U.S. Department Of Energy Federal Energy Technology Centre Climate Change Fuel Cell Program

Grant DE-PS26-00NT40773

Reporting Period
4th November 1998 to 15th July 2001

Final Report Prepared for:-

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Report Completed 30th January 2002

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ABSTRACT

The grant application to the Department of Energy had summarised the basis for the application as follows:-

The firmness of the financial commitment to the project covered by this application can be gauged by the Australian Technology Park Sydney Ltd (ATP) in Sydney, Australia having ordered and installed the first fuel cell in the Southern Hemisphere. The fuel cell was ordered on 11/04/1997 and commenced commercial operation on 11/03/1998 and therefore qualifies under the amended Grant conditions.

The fuel cell is to supply electricity and heat to their National Innovation Centre and to other buildings under construction. These buildings include a Hotel and a Bio-medical Centre. The project is backed by a consortium including the ATP, AUSTA Energy, AGL Retail Energy, Integral Energy, North Power and the Sustainable Energy Development Authority of the Government of NSW (SEDA).

The ATP has taken the leadership position in the application of fuel cells in Australia. The solutions and applications which emerge from the use of the fuel cell installation at the ATP over the next few years will have replication potential throughout Australia.

An integral component of the ATP's mission is the education and training of both the present and next generation of Australian's emerging technologists.

The ATP intends to be the most energy efficient Technology Park and when fully developed will have a maximum demand exceeding 12 MVA.

The ATP therefore represents a unique site within Australia for trialing, demonstrating and awareness raising of new and emerging technologies, products and services.

Since the summary was prepared the fuel cell Consortium has been expanded to include NorthPower of New Zealand and in addition discussions have been held with a number of other supply authorities within Australia and overseas on either joining the fuel cell Consortium or in the case of Urban Energy from Western Australia and the Queensland Department of Energy to replicate the ATP situation. These discussions remain active. In the case of the Western Australian Department of Transport discussions are centred on the placing of orders for three (3) "fuel cell powered buses". It appears that this fuel cell requirement will be met with an order for Mercedes Benz buses as their Government holds an existing contract commitments with that Organisation.

The ATP project has generated much publicity for both fuel cells and for the United States.

Since late 1998 a fuel cell of 200kW capacity has been supplying power to installations at the Australian Technology Park. The 200 kW fuel cell package is an International Fuel Cell (ONSI) phosphoric acid PC25™ power plant and includes electric grid connection as well as grid independent capability for supplying dedicated critical energy loads.

The installation of the fuel cell at the Australian Technology Park has proven and demonstrated to the people of Australia the viability of fuel cell technology as a reliable

premium energy source. The project has generated knowledge that has direct application to the US fuel cell manufacturer that should lead to a further increase in the technology's reliability and hopefully more sales by them to the southern hemisphere.

Australia is well placed to assess, and to benefit from, dispersed generation and the use of fuel cell technology as costs of fuel cell manufacture fall and with a strengthening of the Australian dollar. The Australian Electricity grids are typically characterized by long radial distribution lines. Such systems are particularly good candidates for dispersed fuel cell generation and provide equally interesting opportunities to assess the performance of fuel cells in actual grid-sensitive dispersed generation. Moreover, these same attributes combine with the ability to defer costly transmission line upgrades to remote loads and to supply tailored power to growth pockets having special power quality or reliability needs. Australia also has major reserves of natural gas as well as a major gas distribution network that can facilitate the introduction of fuel cells into remote communities.

This report details the experience gained from 16800 hours of operation of the fuel cell power plant (700 days). The fuel cell commenced operation on the 4th November 1998. The report includes experience up to the 15th July 2001 when the 700 days of operation was reached.

It was intended for the fuel cell's thermal capacity to be utilized by a hotel planned for construction at the Australian Technology Park. Unfortunately the Hotel developer has not installed the hotel as planned. It is intended to utilize the waste thermal output as soon as a viable utilization project is available with the continuing development of the ATP.

700 Hours of Operation for a Fuel Cell Installation at the

Australian Technology Park

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1. Executive Summary.

The fuel cell installed at the Australian Technology Park (ATP) with the assistance of a consortium of organisations from the Electricity Supply Industry (ESI.) provided valuable knowledge that will enable these and other organisations in the Pacific rim of the Southern Hemisphere. The fuel cell has not only performed in accordance with the manufacturer's specification but also in a consistently reliable manner.

The fuel cell in 700 days of operation delivered 2713.938 MWHrs of electricity at an overall efficiency of 40.03% with an availability factor of 95.72% after the elimination of time when the fuel cell was unavailable for service for reasons other than failure issues. These include issues such as upgrading of associated plant, undue delays by Customs etc. The fuel cell had an average time between forced shutdowns of 1658 hours over the whole 700 days of operation. All this performance data concurred with either the manufacturer's specification or with similar experience obtained with the US DOD fleet.

The fuel cell was installed on the roof of an Annexe constructed to house the Locomotive Workshop building's natural gas fuelled boilers for the refurbished Locomotive Workshop's airconditioning heating gas supplied equipment. The Annexe was within 15 feet (5metres) of an Annexe constructed to house one of the building's electrical substations as well as the building's electricity supply switchroom. The proposed hotel was to be installed across the access road to the Annexe and since the footpaths were landscaped a water supply had been installed near the Annexe for the areas watering. Hence within a matter of feet were all the supply connections necessary for the packaged fuel cell unit.

Since the fuel cell was the first to be installed within Australia its connection to the national grids of both gas and electricity had to be obtained. The approval of connection to the electrical grid presented "no problem", this was primarily because the project director had worked within the industry and for the grid owner for more than 34 years prior to commencing the project for the ATP. The grid owner took the view that the fuel cell was to be normally operated in the "grid independent" mode. The fuel cell purchased was equipped with the facility to operate as either grid connected or grid independent. The grid owner was advised that the intention was to supply critical energy loads and that except when the fuel cell was under test it would be operated in the grid independent mode. The fuel cell continues to be "under test". During the commissioning trials it was necessary to have the local grid voltage level reduced. The fuel cell is designed to operate on a 400 volts three phase 50 Hertz grid. The Australian grid is normally a 415 +6%/-4% volts three phase 50 Hertz grid. The ATP system is supplied directly from a substation on site and at the time of commissioning it was operating at 435 volts plus. Control circuit fuses were ruptured as a result of the excessive voltage levels.

The connection of the fuel cell to the ATP gas supply proved initially to be a major hurdle to overcome; this was despite the local gas supplier being a financial contributor to the project. The fuel cell was finally certified for connection to the system but not before the fuel cell gas valve train had been redesigned and duplicate shut off valves installed. After a years successful operation full certification was granted. The Australian certified valves were manufactured by the same manufacturer as the IFC installed valves. These valves had a higher control pressure and an electrical closing energy requirement three times that of the original valves. Relays were installed to control the duplicate valve system.

2. Introduction to the Australian Technology Park.

2.1 ATP Background

At the time of placing an order for the fuel cell the Australian Technology Park had been listed as one of the top 6 projects for the remainder of the decade i.e. to the end of the 20th century in the Australian state of NSW. It was chosen as the site for showcasing emerging energy related technology for the 2000 Olympics.

The ATP continues to be the most energy efficient Technology Park and when fully developed will have a maximum demand exceeding 14 MVA.

The mission of the Australian Technology Park is to:-

- provide international standard research and development facilities to link the resources and skills of three major Universities with the industrial objectives of private companies and government instrumentalities;
- provide a discrete physical location and advanced infrastructure, together with access to the latest applied research in the Universities and encouragement of innovative technologies to assist the development of novel high-value-added products and new industries;
- broaden access to research findings and technological opportunities;
- facilitate technology transfer between research institutions and industry;
- provide incubator facilities for the early stages of commercialisation of new technologies;
- encourage synergy among researchers, designers, entrepreneurs and manufacturers;
- through these activities to contribute to the long-term economic and social interests of the community in accord with the strategic priorities of the city, the state and the nation.

2.2 Creating a World Class Technology Park

The vision to link the three Sydney based Universities i.e. the University of Sydney with the University of New South Wales and the University of Technology, was considered to be strategic in the creation of a world class technology park.

The creation of a world class technology park could address a number of structural problems facing Australia. These problems included the :-

- loss of technology overseas;
- loss of researchers overseas;
- shortage of students entering science and engineering;
- shortage of skilled labour force to take technologies to product;
- duplication and triplication of research effort.

The ATP and other similar Technology projects world wide are therefore not just “another development” project but are of National Significance for the strategic viability of a nation. They will:-

- reduce substantially the loss of a nation’s best technologies;
- reduce the nations brain drain;

- encourage researchers working overseas to return home with their "value added brains";
- enthuse students into science and engineering;
- provide for a highly trained work force capable of taking the best technologies through to production;
- reduce the duplication and triplication of research effort;
- provide significance funding to Universities at a time when funding is being systematically cut;
- provide significantly more job opportunities for students through growth in the technology sectors;
- ensure the development of the superior technologies more economically and quickly;
- provide for and assist with the showcasing of the world's best technologies;
- create urban renewal by the area having life and vitality again.

The role of the ATP is therefore to establish and manage the Technology Park. It must create a synergistic environment to foster research and develop functions, link researchers, business with industry and government as well as to provide vital accommodation for research and new technology based ventures. This must also include access to the "the world's best technologies".

2.3 The Eveleigh Site (Home of the ATP).

Land formerly utilised as the Eveleigh Workshops of the New South Wales State Rail Authority (SRA) was chosen as the site for the ATP. The 14 hectare site comprised a range of derelict buildings together with three more significant and yet rundown heritage buildings which were ultimately to become key components in the development of the ATP. The land had been used by the SRA from the turn of the century for the manufacture and refurbishment of steam locomotives. Steam was the last "great technological era and therefore the site that developed the technology for Australia was a great site from which to launch and showcase the next great technologies for and to Australia.

The land had fallen into disuse with the closure of the SRA Workshops and was subsequently used briefly to house Sydney's "Paddy's Fruit Market whilst that site was being redeveloped. It also contained a small "Black Smith's" business in the corner of the old Locomotive Workshop. Apart from the Black Smith the site was derelict and home to drug addicts. On the surface an area most unsuited for the home of the Australian Technology Park and the showcasing of technology.

2.4 Land Characteristics.

The 14 hectares of land secured from the State Government for the establishment of the Australian Technology Park is both significant in size and location. It is relatively close to the three Sydney participating universities and to the Sydney Institute of Technical And Further Education (TAFE). Other key characteristics of the land include its proximity to the Sydney Central Business District, only 8 minutes drive, and to Sydney's airport, 12 minutes drive and it has direct access to Redfern Station. Redfern is the only station in the NSW rail network through which all routes pass and at which all passenger trains stop.

2.5 Integrated Research Strengths

What sets the ATP apart from other technology parks in Australia, and why it became recognised as the Premier Technology Park in the Asia Pacific Region is the integrated research capability of the participating universities. Approximately 26% of all Australian Government research grants for Australia are shared between these three universities. Since the commencement of operation of the fuel cell the Australian national University has also joined the ATP.

2.6 ATP Tenants

The success of the ATP can be assessed from the demand for space. This demand is not created from a chronic shortage of office space in the nearby Sydney central business district (CBD). In fact currently, there is a surplus of space available in the CBD for renting. The demand is despite the strict entry criteria for tenancy space at the ATP. This entry criteria is included in the Appendices.

The ATP therefore is a unique site for the trialing, demonstrating and awareness raising of new and emerging technologies, products and services. With the strong emphasis at the ATP for ongoing education and training to support the emergence and development of a highly developed skills base through access to public sector research organisations and interaction with both industry and the supporting universities. The mission of the ATP shows that it is the ideal location from which to disseminate from one enterprise and from one industry to another the experience gained from this emerging fuel cell technology and that it is an appropriate technology for Australia.

3 Australian Energy Usage.

Australia's demand for Electricity continues to grow and at the same time the power generation equipment used to meet both the current demand as well as the increasing demand is facing increasing global constraints on environmental impact. In Australia demand for Energy is such that Australia is considered to be one of the largest per capita contributors to "greenhouse gas emissions. Organisations are increasingly looking at ways to co-generate on site via natural gas as a means to reduce energy costs and greenhouse gas emissions. Therefore the issues associated with embedded or distributed Generation to be fully identified and overcome and the knowledge deployed.

Today's world requires unprecedented amounts of electricity for utilities supplying power for commercial, industrial and residential uses. It is essential to our prosperity and pervades every aspect our lives and manufacturing processes. It impacts on every aspect of commerce, industry, transport, domestic living and recreation. It is essential to our economic prosperity, international competitiveness and our standard of living but for the future of the environment these energy requirements must be produced by the most environmentally responsible technology. No nation of the world is contemplating meeting their needs without some use of

fossil fuels. It is therefore essential that the most efficient and environmentally responsible technology is used for the generation of energy from these fossil fuels.

Australia is a relatively small producer of greenhouse gases as it accounts for only 1.4% of the global emissions. However on a per capita basis it is ranked third behind in the OECD and must do "it's part" for the environment.

In the Appendices (15-18) are details of Greenhouse gas emissions and their technology source for 1996 as well as current and projections through to 2019/2020 on Australia's energy requirements.

Since the ATP seeks to be both at the "leading edge" and be energy efficient and environmentally responsible a fuel cell installation was considered desirable. Fuel cells were considered to be the best emerging technology meeting the criteria. The installation would also assist industry and commerce to evaluate the technology as an appropriate technology to enhance their productivity and competitiveness globally. By the installation organisations have had the opportunity to observe and discuss the operation of this leading edge US technology without the need to go overseas where almost 200 similar IFC/ONSI PC25C™ fuel cells were in operation.

4 Dispersed (Distributed) and Premium Power Generation

Distributed generation (DG) refers to small-scale generation at or near to the consumer's premises. Because DG can reduce the need for investment in transmission and distribution networks it and, to some extent, it competes with network owners and their supplies from large generators as such it is viewed as a threat a "disruptive technology". Some of these DG's either use natural gas or a renewable energy source as their primary energy for the generation of electricity. They can therefore have significant environmental benefits in terms of climate change emissions.

Hence DG by fuel cells can offer the benefits of reduced transmission and distribution costs by deferring the need for capital expenditure on distribution system equipment and also minimizing the costs of upgrading or reconditioning power lines. These benefits can be expanded by cogeneration (concurrent production of electric and thermal energy) at new or existing customers. Examples where this would be easily applied with fuel cells include airport traffic management centres, hospitals, hotels, large data or telephone service centres, and the like. In such applications power supply reliability and quality are often critical to the operation of the facility as well. In the case of the ATP the cogeneration capeability of the fuel cell had been intended to be utilised by a proposed hotel. The hotel was to be commissioned prior to March 2000, i.e. in time for the Sydney Olympics. The Hotel developer failed to build the hotel and as such at the present time the thermal capacity of the fuel cell is not being utilised. It remains on the project agenda.

4.1 Fuel Cell History

Fuel Cells represent the principal next generation source of mass energy production due to their combined thermal and electrical efficiency of over 80%, flexibility of application (automobile to utility size power generation), suitability for the burgeoning area of distributed generation, captive power generation for the chemical process industry, and exceptional environmental responsibility in the use of fossil fuels.

Fuel Cells are electrochemical devices that convert the chemical energy of reaction directly into electrical energy. They have been known in concept for more than 150 years and are posed to make significant contributions to power generation.

From a practical point of view, a fuel cell is much like a battery with one important difference. A battery is essentially a chemical energy conversion device with a fixed amount of fuel that runs down when the chemical energy stored in it, either during manufacture or from charging, is consumed. In contrast, a fuel cell has its chemical energy externally replenished and, thus, will continue to generate power as long as fuel continues to be supplied.

Sir William Grove is widely attributed to be the father of the fuel cell. His insights were gained from experiments in 1839 into the electrolysis of water. He reasoned that it should be possible to reverse the process and generate electricity by reacting hydrogen with oxygen.

The term "fuel cell" was coined in 1889 when Ludwig Mond and Charles Langer attempted to build the first practical device using air and industrial coal gas. Attempts in the earlier 20th century to build fuel cells that could convert coal or carbon directly to electricity continued to fail because of a lack of understanding of materials and electrode kinetics. The internal combustion engine had also recently been developed. It's theoretical basis was better understood. Petroleum had been discovered and so the internal combustion petrol engine was rapidly exploited. Electric vehicles and other electrode chemical approaches to energy production were quickly forgotten.

To put all this into perspective, Volta had invented the first electric battery in the year 1800 and Ohms Law had been developed in 1826. The lead acid storage battery was not developed until 1860 and transformers in 1883, the steam turbine in 1884 and the induction motor in1888 as such fuel cells were envisioned at the very dawn of electrical knowledge.

The first successful fuel cell device resulted from an invention in 1932 by Francis Bacon. He improved on the expensive platinum catalysts used by Mond & Langer with a hydrogen cell which used a less corrosive alkaline electrolyte and used inexpensive nickel electrodes. The challenge was daunting such that a quarter of a century passed before Bacon and his co-workers were able to demonstrate, in 1959, a 5 kW system capable of powering a welding machine. It was in the same year too that Harry Karl Ihrig of Allis-Chalmers demonstrated a 20 horse power fuel cell powered tractor.

It was the American space exploration missions however that saw a need for a new energy source and this brought about a major focus into fuel cell technology development. Fuel cells occupied a key role due to their high energy density and because their by-product water was needed for drinking water and to cool spacecraft electronic equipment. Yet even after developing it for space bringing the technology for use on earth also proved to be a difficult proposition. It has taken over 30 years and more than two billion dollars of research to date and now we are just approaching the commercialisation of fuel cell technology.

A variety of fuel cells are in the various stages of development. Fuel cells are usually classified by the type of electrolyte used in the cells. They include the proton exchange membrane fuel cell (or PEM), the alkaline fuel cell (or AFC), the phosphoric acid fuel cell (or PAFC), the molten carbonate fuel cell (or MCFC) and the solid oxide fuel cell (or SOFC). I

have listed these fuel cells in their approximate order of operating temperature i.e. from about 80°C for the PEM. cell, 100°C for the AFC, 200°C for the PAFC, 650°C for the MCFC and over 700°C for the SOFC. Early SOFC units operated at 1000°C and following recent attempts to reduce this temperature so as to minimise the thermal stresses within the cell, this maximum temperature has been reduced to between 700 and 800°C.

Of all of the fuel cells being developed, apart from the PAFC fuel cell only small experimental research based cells have been developed. The PAFC from the ONSI Corporation in America is considered commercial and is the one in operation at the Australian Technology Park.

4.2 The Phosphoric Acid (PAFC IFC PC25) Fuel Cell

Phosphoric acid fuel cells have been in continuous development since the mid-1960's incorporating substantial governmental and private industry funding. The major technology developer being United Technologies subsidiary company International Fuel Cells. Commercial production of the 200 kW phosphoric acid fuel cell began several years ago with the release of the ONSI PC25 Model A which was followed by the Model B. As far as the manufacturer is concerned the release of the Model C commenced true commercialisation of the product. The "25" essentially represents the twenty-fifth design of a series that begin in the 1970's. with the Model A, the alpha release, followed by the Model B, the beta release.

The PC25 Model C, the 200 kW phosphoric acid fuel cell delivered by International Fuel Cells under it's subsidiary ONSI is the technology covered by this report. The unit is a completely automatic commercial power plant designed for unattended outdoor operation weighing 40,000 pound (18,140 Kg), in a beige container like box 18 feet long x 10 feet wide x 10 feet high (5.5 m x 3.0 m x 3.0 m) as shown in the Appendices.

Unlike a battery, fuel is continuously supplied by a Fuel Processor to the cell's negative electrode or anode. Concurrently, oxidant, which is oxygen from ambient air, is continuously supplied to the cathode or positive electrode. Like a battery, a fuel cell consists of two conductive plates separated by an insulating barrier containing an electrolyte. The reaction of hydrogen at the fuel anode is:

$$H_2 \longrightarrow 2H^+ + 2e^-$$

and for the oxygen at the cathode i.e. the air side:

$$\tfrac{1}{2} O_2 + 2H^+ + 2e^- \longrightarrow H_2O$$

Since the electrolyte is an electrical insulator, the electrons are forced to travel via an external circuit and thereby produce a flow a flow of electrons. When sufficient electrons flow this results in electrical power. The hydrogen ions travel through the ionically conducting electrolyte to recombine with the electrons and oxygen to produce water vapor.

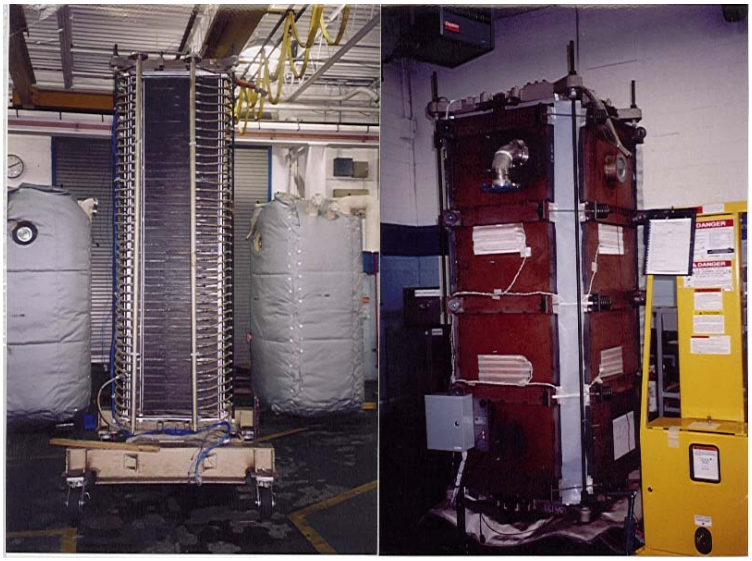
To an adequate and efficient reaction, a highly dispersed platinum catalyst is added to the anode and cathode adjacent to the electrolyte. In the phosphoric acid fuel cell, this is a paper-

like material imprinted with a platinum/Teflon™ based "ink" (a carbon platinum catalyst). The electrolyte is a 100 percent solution of phosphoric acid (H_3PO_4) dispersed within a porous silicon carbide layer. Phosphoric acid is considered a relatively mild acid from a chemical viewpoint and is contained within the cell.

Like a battery, the output voltage produced by a fuel cell decreases as more current flow is drawn by the circuit. Thus, higher current flows result in lower voltage. Typical operating conditions in a phosphoric acid cell are 210 amps per square foot (225 mA/cm^2) yielding around 0.60 volts per cell. In contrast, at an 80 percent reduction in current density the cell potential would increase to around 0.70 volts. These cells are stacked in series to provide the total voltage delivered by the cell stack. Over time the cell output voltage decays and this is one of the critical factors in determining the life of the fuel cell stack. The graph of the decay in the ATP fuel cell total stack voltage output is shown on the following page. During the 700 days of operation of the ATP fuel cell the voltage output decayed from 166.8 volts to 158.46 volts. A reduction of 6.2% in almost 17000 hours operation. This compares favourably with the reported decay data from the US DOD fleet and reported to the 2000 Fuel Cell Portland Seminar. These units had decayed 7% after 10,000 hours operation for Model A&B units and 5% for models similar to the ATP unit i.e. Model "C" units.

Cell voltage is also a composite result of a number of other technical and practical factors. These include: the amount of catalyst loading, temperature, pressure, reactant concentration, and the age of the cell. The latter arises from changes in the catalyst's physical composition or even by poisoning of reactive catalyst sites by contaminants.

The POWER SECTION of a practical fuel cell needs to generate electric power at reasonable voltage and current outputs. In the ATP fuel cell the production of 200KW output delivered from the fuel cell stack at about 1400 amps and 155 volts DC requires an assembly of 256 cells with a cell area on the order of 5.5 square feet (0.5 m^2). This fuel cell stack is a package of approximately 36 inches (0.9 m) square and 9.5 feet (2.9 m) tall.



The adjacent photo on the far left shows an early model cell stack cell with two new cell stacks ready for installation in a new power plant. The cell stack on the immediate left is a cell stack under test and prior to being thermally insulated.

Since the phosphoric acid cell stack operates at 350°F (177°C), a high purity circulating water loop within the power plant provides a means: to heat the unit to operating temperature during startup, to extract heat during operation, and to cool the stack at shutdown. Cell stack thermal management is provided by end cooler plates and intermediate separator coolers that are part of this circulating water loop. A typical power plant converts about 40 percent of the fuel's

lower heating value to electricity and can supply about 40 percent of the balance as recoverable thermal energy for combined-heat-power customer use.

The phosphoric acid fuel cell uses gaseous hydrogen as the reactant. The fuel is produced by a fuel processor that is a steam gas reformer which converts natural gas or other hydrogen concentrated fuel gas into a hydrogen rich fuel for the cell stack and in the process vents off the carbon content of the fuel as carbon dioxide. The process reacts steam and fuel, such as natural gas, within a supported nickel catalyst bed, to remove any sulphur, at 1650°F (900°C) to reduce the fuel to hydrogen and carbon dioxide. This reaction is:

CH_4 (methane)	$+ H_2O$	$\longrightarrow$	$3H_2 + CO$	Process requires heat
CO	$+ H_2O$	$\longrightarrow$	$H_2 + CO_2$	Process provides heat
CH_4 (methane)	$+ H_2O$	$\longrightarrow$	$4H_2 + CO_2$	Net heat requirement.

This reaction requires heat to warm the feedstock to reaction temperatures and to supply the net endothermic reaction. Spent unused hydrogen fuel that has not been utilised within the fuel cell stack is burnt within the reformer assembly to produce the superheated steam for the process.

The water for the steam to react with the natural gas is generated by the cell stack's heating of recovered condensed water from the fuel cell. More water vapor is available than is needed for the reforming process and this is returned to the cell stack cooling system.

A fuel cell stack produces unregulated, variable potential direct current due to its battery-like characteristic of lower voltage at higher current draws or as the cell stack catalyst ages and electrolyte is removed from the system. Variable DC input from the cell stack is converted into a stabilised AC voltage of premium quality, voltage, frequency, and phasing for the customer and/or for supply to the grid. The power plant must operate smoothly during load transitions in the site's electrical network or the grid network.

The IFC PC25™ Model C fuel cell power plant is a self contained unit that is capable of fully automatic operation and of maintaining an appropriate grid/customer interface under all normal conditions.

4.3 Distributed Generation and the IFC PC25 Model C Fuel Cell.

Historically, small-sized conventional engine generators have not been able to deliver the efficiencies, availability potential, and reduced maintenance characteristics necessary to make dispersed generation a serious option. However, the inherent benefits of electrochemical energy conversion now make fuel cells a potentially viable option for dispersed generation. This is due to the fuel cell's:

- reduced emissions,
- relatively high efficiency in the sub-megawatt size range,
- low noise and vibration levels,
- potential for longer times between scheduled and unscheduled shutdown maintenance than engine driven systems, and
- ability to perform scheduled quarterly maintenance while the power plant is operating.

The result of these attributes, is such that the PC25™ Model C 200 kW fuel cell power plant, is now a proven technology for this important sector of the market and with the use of multiple units both the reliability and available load capability that can be supplied is increased.

The IFC/Onsi PC25phosphoric acid fuel cell converts about 40 percent of the fuel input, on a lower heating value basis, into electric energy. An additional 40 plus percent of thermal energy is available as $65^{O}C$ hot water. Examples of potential cogeneration applications include using the fuel cell technology to supply some or all of the needs of a hospital, nursing home, hotel, college, etc. For many of these loads, power reliability and quality is also becoming increasingly important.

For these reasons, dispersed generation locations at hospitals, computer centres, and the like are considered to be attractive market entry prospects for fuel cells. One mode of this application would be as a premium power source where the fuel cell dispatches load in parallel with the grid during normal periods, and reverts to a grid independent supply for premium local customer loads during any grid disturbance. This is the installation arrangement at the ATP.

DG, particularly in combination with the premium power quality benefits of fuel cells, is attracting increased utility industry and customer attention. Electric cooperatives have a particular interest due to an inherently low customer density, growth patterns at the end of long lines, and a continued influx of consumers and high-tech industry seeking to diversify out of urban environments.

The relatively small size and higher electric-to-thermal ratio of fuel cells, like the commercially available ONSI PC25 Model C™ phosphoric acid fuel cell power plant, also makes cogeneration a better match for the types of customers and dispersed generation loads. Further contributing factors are the fuel cell's low emissions, minimal site noise and vibration, on-line quarterly maintenance, and the Model C's potential for 95 percent availability and a 2000 hour mean time between forced outages. Fuel cell ownership, installation, and service in cogeneration applications also represent potential opportunities for diversification revenues at the transmission or distribution levels, which are additive to the benefits of prospective cost deferrals of distribution and transmission construction costs due to dispersed generation.

Of particular interest are "premium power" applications. In this mode the power plant normally dispatches to the grid at a full 200 kW output. However, if the grid experiences a problem, the fuel cell reconfigures itself to support a grid independent load. This concept produces the most attractive set of fuel cell economics as the fuel cell capital cost is spread over the maximum power production since the power plant is operating at a full 200 kW output dispatch level most of the time while concurrently adding value by supporting a premium power grid independent load. The existing Model C design requires about 3.5 seconds to re-configure when switching modes from grid connect to supporting a premium power grid independent load in the case of a grid upset.

At the Australian Technology Park the fuel cell installation utilizes an external closed operating transfer switch for reconnection to the grid in the event of a fuel cell interruption. The critical loads connected at the ATP both can handle the minor transfer re-configuring, in the case of the AC3 super computer installation a separate customer installed UPS overcomes

the transfer and in the case of JJR it is not an issue. AC3 require the UPS in any case for periods when the fuel cell is offline and the super computer is supplied from the back-up national grid supply.

The power plant's built-in grid interconnect protocols worked well at the Australian Technology Park site. In the Appendices is a report of the loss of the Sydney Grid system on 12th October 1999. During this grid shutdown the critical customer supplied from the fuel cell did not lose supply. Since the fuel cell commenced operation on the 4th November 1998 and since the critical energy customers were connected to the fuel cell grid with the national grid as a back up to the fuel cell the critical customers have not lost supply on any occasion.

5 Installation

The installation of a fuel cell at the ATP since it was the first Australian installation required the installation to be designed to Australian acceptance requirements. No difficulties were experienced in obtaining approval for it's electrical connection as the local supply Authority after being supplied all design data gave permission for it to operate as a premium power source, except whilst under test and in an emergency situation. The fuel cell has normally operated in the grid connected mode and with the premium supply customers connected via the grid independent capability. The fuel cell system derived is considered to be under test and as such the fuel cell has operated normally connected to the grid. The electrical layout of supply at the ATP is included as Appendix 9.

Australia had fully adopted the metric system in 1996 and as such from the very beginning one of the issues was conversion of all requirements for the installation to metric. Because a variety of units are used for the same requirement eg pounds per square inch, "inches of water or mercury" there was a need to constantly change units to Australian metric unit when working or placing orders. To assist this process and following the commissioning of the fuel cell ONSI provided a small program. Appendix 3 details conversion data used during the installation.

The fuel cell was able to be located on the roof of an Annexe constructed to house the Locomotive Workshop building's natural gas fuelled boilers for the airconditioning heating. The Annexe was within 15 feet (5metres) of another Annexe constructed to house one of the building's electrical substations as well as one of the building's that housed the electricity supply switchroom. Hence within a matter of feet were connections available to both the local grid and to a natural gas source. The roofs of both Annexes were used, one for the fuel cell and one for the fuel cell's cooling module. The installation location is further detailed in the Appendixes.

The connection of the fuel cell to the ATP gas supply was initially a major hurdle to overcome; this was despite the local gas supplier being a financial contributor to the project.

As indicated in Appendix 7 the fuel cell was finally certified for connection to the system but not before the fuel cell gas valve train was redesigned. Initially the IFC operator was stopped from coming to Australia until some guarantee was received from the gas supplier that gas for testing would be provided. The Gas supplier, who also was a project sponsor, required all control valves in the gas valve train to be Australian certified and duplicated. Concern was also raised on the control of valves by the fuel cell computer and initially the gas supplier required the valves to be "hot wired". The Australian certified valves were manufactured by the same manufacturer as the IFC installed valves. They did however have a higher control pressure and their electrical closing load was three times that of the original valves. Relays were installed to control the duplicate valve system.

The modified valve train is shown in the photo on the previous page.

Following the alterations to the valve train approval was granted to start the fuel cell provided proof was provided that the system could handle a "stoichimetric" test of the system prior to a restart following a shutdown. Advice from IFC was that it was not possible to create a "Stoichimetric" condition and as such it was not possible to provide the proof sought. Following one year's successful operation and the provision of all available information on international experience and acceptance testing the gas supplier certified the plant for ongoing operation.

6. Results and Discussions

6.1 General

The Australian fuel cell operational experience has replicated closely that reported for the US DOD fleet at the fuel cell 2000 Seminar in Portland Oregon. The year following the fuel cell's commissioning and even in the period after the installation of the fuel cell onto it's foundations and leading up to the commissioning was a period of above average rainfall. The Appendices provide some Metrological data on Australia and of Sydney in particular. The following summarises the "ATP fuel cell Experience":-

- During the first year of operation a number of shutdowns were attributed to (i) failure of Inverter drive boards, (ii) failure of the Invertor current measuring devices (LEM's), (iii) possible Master DSP or Slave DSP failures and (v) a failure of Fan 165. It was realised after several repeat failures in the current measuring LEMs where corrosion was also evident that all the failures were immediately below a section join in the roof. The joint gasket was easily removed and re-caulked, and in the almost 20 months since the re-caulking no failures of these devices has occurred. The method of caulking initially used by IFC is considered to be inadequate for the hash Australian conditions. IFC were advised of this issue.

- The fuel cell is a nominal 400/230volts 3phase 50Hz system whereas the current Australian system in a nominal 415/240volts 3phase 50Hz system. System voltage variations in the Australian system are expected to be maintained within a +6% /-4% limit. These limits are maintained by adjustment of fixed transformer taps at the local transformer and by automatic transformer tap changing by drop compensation at the "Zone transformer". At the time of commissioning the local transformer was operating with an output level of 435volts and probably even higher in early hours of the morning. However in attempting to start the fuel cell the small control fuses

- As indicated earlier the fuel cell is located on the roof of the Annexe and is exposed to the southern winds blowing across from the "bay" about one (1) mile away and also to the hot afternoon "western" sun. The sun temperatures experienced during the 700 days of operation tested the fuel cell's ability to control the disposal of the waste heat. The fuel cell experienced days where the ambient temperature exceeded 105°F. The incoming gas supply temperature gives a good indication of the extreme temperature conditions faced by the fuel cell. When the day ambient temperature was 105°F the recorded temperature of the incoming gas was 120°F and the exit temperature of ventilation air from the fuel cell was almost 130°F. The fuel cell is designed for an upper ambient limit of 105°F. These high ambient temperatures lasted on each occasion for several hours were recorded every day for almost a week. Temperatures close to the extreme were recorded every day for almost three (3) weeks. The severity of the conditions is evident in the Appendix detailing the "bushfires in Sydney. In addition to these extreme weather conditions and since the fuel cell commenced operation it has endured an unprecedented hail storm. Appendix 12 details the enormity of that storm. These conditions place an onerous burden on the fuel cell housing to "weather the condition" and this is an area that future fuel cells to Australia need to be better equipped to handle. Appendix 10 includes as part of the operational experience data photographs of rust that was evident in the fuel cell even during the first year of operation. The rust following treatment remains an ongoing issue. IFC have been advised of this issue.

- During the early months of operation several "hot shutdowns" were experienced i.e. shutdowns where the cell stack and system were cooled in an "uncontrolled" manner. IFC considered that these were caused by the coolant pump controller becoming unstable due to sags in the grid system. The fuel cell has recorded monthly one or two occurrences where either a greater than 5% unbalance or a +10% or a -20% in the nominal grid voltage has been encountered. IFC immediately provided a new pump controller at no cost to overcome the issue. There has been no further problem.

- Service by IFC has been above that normally expected of suppliers. IFC staff have always been available for assistance, if and when required. Two examples of many are worth mentioning:-

    - As the ATP fuel cell was the first unit to experience the Y2K issue a call was received from Gary Cingel of IFC about eight hours prior to the turn of the century to advise "I am available if you require me tonight".
    - At time of a shutdown due to a smoke detector alarm, I was on my way to attend to the shutdown, a ¾ hour journey, and received a call from Gary Cingel offering assistance. On my arrival at the ATP I returned the call and found that the call was from Alaska, where he was working at the time.

- During the 700 days of service the ATP fuel cell delivered 2713.938 MWHrs of electricity at an overall efficiency of 40.03% with an availability factor of 95.72% after the elimination of time when the fuel cell was unavailable for service for reasons other than failure issues. These include issues such as upgrading of associated plant, undue delays by Customs etc. The fuel cell had an average time between forced shutdowns of 1658 hours over the whole 700 days of operation. All this performance

data concurred with either the manufacturer's specification or with similar experience obtained with the US DOD fleet.

- One issue that caused several shutdowns was the modem. Following a failure of the fuel cell modem and so loss of the remote monitoring capability by either myself or IFC a replacement modem was supplied and fitted. It was noted that the fuel cell shutdown almost as soon as the fuel cel was called up remotely. The fuel cell was restarted locally and the telephone line connection to the fuel cell disconnected so that the automatic daily monitoring by IFC would not shut the fuel cell down. Whilst IFC did not agree, initially, with the claim that the fuel cell was being shutdown by the new modem, they undertook testing of the current new modems and found that indeed the modem was triggering a shutdown. It is to their credit that they undertook testing when they had no other reports of a modem issue only my word that I believed that the modem was an issue.

6.2 Mean Time Between Forced Shutdowns.

It has been reported earlier that during the 700 days of service the ATP fuel cell delivered 2713.938 MWHrs of electricity at an overall efficiency of 40.03% with an availability factor of 95.72% after the elimination of time when the fuel cell was unavailable for service for reasons other than those associated with the plant failure. These include issues such as upgrading of associated plant, undue delays by Customs releasing replacement parts etc. The fuel cell had an average time between forced shutdowns of 1658 hours over the whole 700 days of operation. All this performance data concurred with either the manufacturer's specification or with similar experience obtained with the US DOD fleet.

6.3 Cost Benefit

The benefit of the fuel cell to the Australian Technology Park was more than just the cost to produce electricity and utilisation of waste heat. The cost benefit was primarily the opportunity to showcase a leading edge viable technology to the "pacific rim" nations, Australia in particular. However it is nevertheless important to consider the actual costs of the project in this demonstration. Another project benefit was the reduction in greenhouse gas emissions. It is estimated that more than 2000 tonnes of greenhouse gases has been eliminated from the environment.

6.3.1 Project Financial Basis.

The ATP formed a Consortium to finance the fuel cell. The Fuel Cell was principally financed by Australian Technology Park Sydney Ltd (following a restructuring of the ATP ownership the Australian Technology Park Precinct Management became the fuel cell owner) and the consortium provided funds on the basis of receiving a small dividend and regular reporting on the fuel cell's performance. The consortium comprises AUSTA Energy of Queensland, the Principle Sponsor, AGL Retail Energy of Sydney, the Gold Sponsor, Integral Energy of Sydney, Powerco of New Zealand, the Silver Sponsors and North Power (now Country Energy) as a Sponsor. Cutler Hammer, Dow Coring, MM Cables provided assistance with equipment and the New South Wales Government Department SEDA provided a Aus$260,000 (approx.$130,000) loan with a reduced interest rate, for some of the cost. Total Consortium funding received was Aus$650,000 (US$325,000 approx) of which $115,000 (US$62,500

approx) was for Contractor expenses, training and fuel cell operational costs as well as the raising of funds as well as the equipment contributions and that from the critical energy customers and the funds from the grant. The project's viability was due to the support of these Sponsoring Organisations and to the support of the US Department of Energy who contributed US$200,000 (approx. Aus$400,000) towards the project under their Climate Change support scheme.

In addition to the above funds the organisations connecting to the fuel cell as requiring critical energy were required to make a contribution to the project based on their avoidance costs. These critical customers would have had to install and maintain an alternate backup energy source. Their level of contribution was set at 70% of their identified avoidance cost. A "win-win" situation. Since ATP agreed to reduce the %age levied to exclude the UPS equipment the actual funding received from this arrangement were Aus$140,000 (approx. US$70,000).

The fuel cell installation as indicated earlier being sited on the roof of the two Annexes and adjacent to all services was a minimum cost installation. As the Locomotive Workshop was being refurbished concurrently at the time of the installation and contracts had been placed for the installation and testing of the airconditioning boilers and therefore the exhaust flue stacks they were installed and then repositioned even though their final location was known prior to their initial positioning. The costs of their repositioning have therefore been excluded from the installation costs. Additional costs were also avoided by the Sponsorship of the project by MM Cables (now Pirelli Cables) and Cutler Hammer. These companies supplied equipment towards the project. Value of their contribution was approximately Aus$60,000 (approx.US$30,000.)

Hence funding received from all sources, excluding the loan totalled approx. Aus$990,000 (US$445,000) and the loan was valued at Aus$260,000 (US$130,000) which funded the shortfall costs by ATP.

6.3.2 Installation Costs.

Cost of the fuel cell to the ATP	Aus$872,000	(US$627,500)
Shipping costs.	Aus$41,000	(US$14,000)
See note:- 1.		

The following costs were incurred in the installation:-

• Steelwork for stairs and foundations	Aus$26,000	(US$13,000)
• Plumbing costs	Aus$ 4,000	(US$2,000)
• Modification to gas valve train	Aus$ 3,000	(US$1,500)
• Electrical installation incl. Switchboard *	Aus$38,000	(US$21,000)
• Nitrogen installation	Aus$1,000	(US$500)
• Crane hire	Aus$5,000	(US$2,500)
• Misc. costs	Aus$5,000	(US$2,500)
Total Project cost	Aus$995,000	(US$684,500)

Note:-
i) Costs in US Dollars at an exchange rate of 1US$=0.5 cents AUS however when the fuel cell was ordered the Australian Dollar rate to the US Dollar was 72 cents and now at the time of writing this report the value is down to almost 50 cents to the US Dollar. Hence it is almost

impossible to give an exact project cost evaluation. The contract with ONSI for the fuel cell required a staged payment system. The cost therefore quoted as paid for the fuel cell has been quoted as the cost based on the rate of exchange at time of the order.

ii) Above costs do not include supervision of the installation by the Project Director since this was covered by other duties and not separately invoiced.

* Some costs incurred needlessly since it had been proposed to include a high temperature supper conductivity demonstration as part of the power supply. Following MM Cables joining with Pirelli Cables this demonstration was abandoned.

6.3.3 Energy Costs.

Funding shortfall for the installation was to be provided by the ATP. The shortfall was approximately Aus$140,000 (US$70,000) after allowance for funding supplied for other than towards the capital cost, this was paid from the low cost loan provided by SEDA. The balance of the loan was used to cover the shortfall prior to receipt of the US Grant and funding from the critical energy customers.

During the 700days of operation the fuel cell produced 2,713,938 KWHrs of electrical energy and at the same time as a "bi-product" approximately the equivalent of 3,000,000 KWHrs of "hot water at 65°C. Electrical energy as well as natural gas for the fuel cell supply at the Australian Technology Park is purchased under contract. The average unit cost per KWHr for the electricity under the contract during the 700 operational days was 7.25 cents (US 3.6cents approx) per KWHr and if the energy had been supplied via a "General Supply Tariff the unit cost would have been 10.12 cents. Energy is sold to the critical energy customers at the local Supply Authority's General Supply Tariff rate i.e 10.12 cents (US5.0cents). Hence the avoided cost for fuel cell produced energy was Aus $275,265 (say US$135,000). Since the waste heat energy could have been utilised to avoid the purchase of "off peak" electricity at 3 cents per KWHr the waste heat has been assigned a value equivalent to the "off peak" electricity rate i.e. Aus $90,000 (US$45,000). Total value of energy delivered approx Aus$365,000 (US$180,000).

The fuel cell was, as indicated supplied from natural gas. In the period under consideration a total of almost 700,000 cubic metres of gas were utilised i.e. 24,000 Gj (LHV) or 27,000Gj (HHV) at an average cost of Aus$5.2 (US$2.6) per Gj (HHV). Hence the cost of the gas utilised during the 700 days of operation was Aus$140,000 (US$70,000).

Other costs are costs associated with maintaining the fuel cell in working order and these include scheduled maintenance, filters ,resins and charcoal used in the water treatment system replaced whilst the fuel cell is working, and labour during the annual maintenance as well as unscheduled parts failure. The estimated cost of the consumables and labour to install during the 700 days of operation has been costed at approx Aus$48,000 (US$24,000).

Whilst cost for supervision of the project have been excluded as the officer responsible has carried out the duties in conjunction with other activities it would be appropriate to place a value on these costs. It is estimated that a value of Aus$40,000 (US$20,000) should be included.

In summary

Installation shortfall (approx)	=Aus$130,000	(US$65,000)
Value of Energy Delivered	= Aus$365,000	(US$180,000)

Gas utilised	= (Aus$140,000)	(US$70,000)
Maintenance etc Cost	= (Aus$48,000)	(US$24,000)
Supervision etc. Cost	= (Aus$40,000)	(US$20,000)

Hence based on the above if the waste heat had been utilised rather than wasted the project during the first 700 days of operation would have returned a dividend of Aus$122,000 (US$61,000). As the waste heat (see below) was not utilised this dividend was not realised, but the fuel cell as a viable project cannot be held responsible for this. The Consortium members were to receive a 5% dividend on their contribution from the projects income, no dividend has been paid.

6.3.4 Waste Energy Utilisation

As indicated earlier the project did not utilise any waste heat. At the time of placing the order for the fuel cell an organisation had undertaken to install a Hotel adjacent to the fuel cell installation. This project was to fully utilise the waste hot water and they were to make a contribution towards the project's cost. As the hotel was not commenced in time to be used for the 2000 Olympics, the organisation cancelled the project. Details of the project are included in Appendix 14. The utilisation of the waste hot water remains outstanding, but as and when an opportunity presents itself it will be activated.

6.4 Reliability

During the 700 days of service the ATP fuel cell delivered 2713.938 MWHrs of electricity at an overall efficiency of 40.03% with an availability factor of 95.72% after the elimination of time when the fuel cell was unavailable for service for reasons other than failure issues associated with the fuel cell. Eliminated time includes time associated with the upgrading of associated plant system, undue delays by Customs processing the replacement parts etc. One issue that created significant downtime was one module board that was unavailable from IFC (ONSI) for more than 8 weeks. This module was associated with the Grid Connect/Grid Disconnect and was out of production at the IFC supplier. The testing of the replacement board required the manufacturers' test rig to be "reset" for prior to release. This delay caused undue concern from the critical energy consumers. Fortunately ATP had installed a duplicate low voltage grid back up supply. As indicated in the "ATP system" diagrams there is a manual transfer facility between one grid and the fuel cell supply with an automatic transfer to a second grid if they both should fail. IFC did all possible to solve the issue, but the delay if it had been the "norm" for replacement parts would have created a "black eye" for the technology and for IFC in particular. However IFC were always very responsive to the supply of parts.

The fuel cell had an average time between forced shutdowns of 1658 hours over the whole 700 days of operation. All this performance data concurred with either the manufacturer's specification or with similar experience obtained with the US DOD fleet.

7. Conclusions

The fuel cell installation at the ATP has demonstrated to Australia and the region that fuel cells are now a reliable commercial and viable energy source for premium power. The project

has demonstrated that the manufacturer's claims of both reliability and efficiency are accurate.

A major barrier to the further introduction of fuel cells to Australia has been the increase in the cost of fuel cells as well as the deterioration in the value of the Australian Dollar. A graph in the Appendices details the change. Despite the high costs indicated for fuel cell systems they are even now more cost effective than photovoltaic systems for the reduction of greenhouse gases in Australia. This is currently a basis to justify further sales of fuel cell technology until such times as mass production and other ways are found to establish a reduction in fuel cell technology costs or the critical nature of the supply requires a "battery" of fuel cells.

The battery of fuel cells concept overcomes issues, mentioned above, associated with forced down time and maintenance generally. Many situations exist where the local critical loads are less than the capacity of a single 200 kW unit and therefore the reliability of the single unit becomes an issue. The ideal situation is where the load to be supplied approaches the full capacity of two units therefore with three units in the system all would operating normally at 2/3 capacity and under emergency at full capacity. An examination of site data from IFC indicates that most sites operate with one unit and only a few with 2 or more units. It would appear to therefore be justified in reducing the IFC modular capacity to accommodate this scenario. Benefits of a reduced capacity would not only include the increased opportunity of more sites with multiple units but fuel cells at more sites with smaller critical load requirements. The current cooling module is considered sufficiently compact to be retained with it's current level of cooling capacity. However since the unit has three fans it is considered that two units with two fans each could be substituted and interconnected to meet the firm (emergency) capacity of the composite interconnected three module fuel cell installation.

8. Acknowledgements.

The Project Director wishes to recognise the support of the Board and Management of the Australian Technology Park in making possible such an ideal site to showcase fuel cell Technology as well as their encouragement and support given.

The support and assistance of all Consortium members and project Sponsors as well as the assistance of the United States Government in providing support to the project under "the US Climate Change Program" has made this project viable. I believe that through the support of all these Organisations the knowledge gained and dispersed within the region has brought about an increased awareness in the emergence of fuel cells and of their potential to meet the challenge to reduce greenhouse emissions and at the same time meeting the communities need for a reliable local supply of premium power.

I cannot conclude this report without recognising the support of my wife and of the staff of the fuel cell manufacturer International Fuel Cells (ONSI) who have always been there for me. In particular from IFC I would like to thank Herb Healy and Gary Cingel who have become great friends throughout the project.

Fuel Cell Report

Appendices

US Grant DE - PS26
00NT40773

View of Sydney Australia

Location

The Australian Technology Park is situated at the centre of a triangle formed by the three participating universities – The University of New South Wales, The University of Sydney, and University of Technology, Sydney, and NSW TAFE.

ATP is only 12 minutes from Sydney's airports and 8 minutes from the Central Business District, with links to major transport routes and direct access to Redfern Railway Station.

Through the links with the three participating Universities and TAFE, tenants at the Park have access to 15,000 qualified staff, 120,000 students, plus the resources and infrastructure of these leading educational institutions.

The three participating universities provide a ready supply of engineers and scientists, and access to Australia's best research facilities. 25 per cent of Australia's university related R&D budget is managed by these universities.

These institutions have world class strength in ten generic technology areas around which the ATP is building clusters of companies.

THE UNIVERSITY OF NEW SOUTH WALES

UTS

TAFE

The University of Sydney

EXIT
EXIT
NATIONAL INNOVATION CENTRE
CONSERVATORIUM OF MUSIC
LECTURE THEATRE
FUNCTION ROOM
EXIT

from steam trains to silicon chips

NSW Heritage Office

The past, present

and future of the

Eveleigh Railway

Workshops

Eveleigh's present future

Conservation

"Heritage conservation" is the general term used to describe the actions taken to stop the deterioration and loss of historic items or buildings. Sometimes this can mean repairing or restoring something to original, working condition. Other times it can mean just making an item stable enough so that it no longer deteriorates and can be preserved indefinitely.

At Eveleigh, a great deal of work has been done conserving the historic Loco Workshops and New Locomotive Workshop. This has involved reinstating lost or damaged brick- and stonework and replacing damaged windows and doors with modern reproductions of the originals. The iron skeleton of building (its columns and trusses) has been cleaned and repaired. But what about the machinery?

In 1997 the Heritage Office made a grant of $300,000 over three years to assist in the conservation of the historic machinery on site. These funds are to be matched by the Australian Technology Park, providing $600,000 total for the work.
A full-time conservator has been appointed to conduct the work and he hopes to return as much of the equipment as possible to working condition, for public display and so it can be used in future restoration work on steam locomotives.

Development

The Australian Technology Park (ATP), which occupies the former Eveleigh Locomotive Workshops, is a joint venture by the University of NSW, University of Sydney and University of Technology, Sydney, operating in conjunction with business and government. It is a home for a mix of science and technology businesses, university research facilities, classrooms and schools and exhibition spaces. The focus of the ATP is to help make links between emerging technologies and real-world needs and to meet changing needs in a changing world.

The ATP occupies three historic buildings: the Locomotive Workshops, the New Locomotive Workshops and the Works Manager's Office. The large Locomotive Workshop building in the main part of the ATP and houses a mix of large & small businesses and research facilities and will eventually house the School of the Future. The New Locomotive Workshop, now the **National Innovation Centre**, was the first of the ATP buildings to open. The Work Manager's Office is the ATP's **International Business Centre**.

Only fully opened in 1998, the ATP will keep expanding, with further development planned on the site, including further research facilities, function centres and a hotel.

future work on the past

Further work is being done on Eveleigh's history. The conservation of historic machinery is only just beginning and more historical research will also be done on site. The public is invited to help:

Labour historian Dr. Lucy Taksa has been recording oral histories of the site and is very interested in speaking with former Eveleigh workers with stories to tell about the workshops.
She can be contacted on **02 9385 2010.**

Conservator Dave McBeath has been appointed to conserve the historic machinery at Eveleigh. If you would be interested in sponsoring conservation work, contributing to the conservation fund or volunteering to do some of the hands on work yourself, please contact him on **02 9310 5409.**

NSW Heritage Office
Level 11, Signature Tower, 2-10 Wentworth Street, Parramatta NSW
Postal address: Locked Bag 5020, Parramatta NSW 2124
Tel: (02) 9635 6155 Fax (02) 9891 4688

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Thanks to: **Don Godden, Dave McBeath, Lucy Taksa, 3801 Limited, State Rail Authority Archives, Mitchell Library, Australian Technology Park** – Photos: **State Rail Authority Archives, MacLaren North**

Written and conceived by MacLaren North

ISBN 0-876415-10-X
H098/22
Print Post Approval No.PP 255003/01429
© Crown copyright 1998
Printed April 1998
Designed by Harley & Jones

NSW Heritage Office

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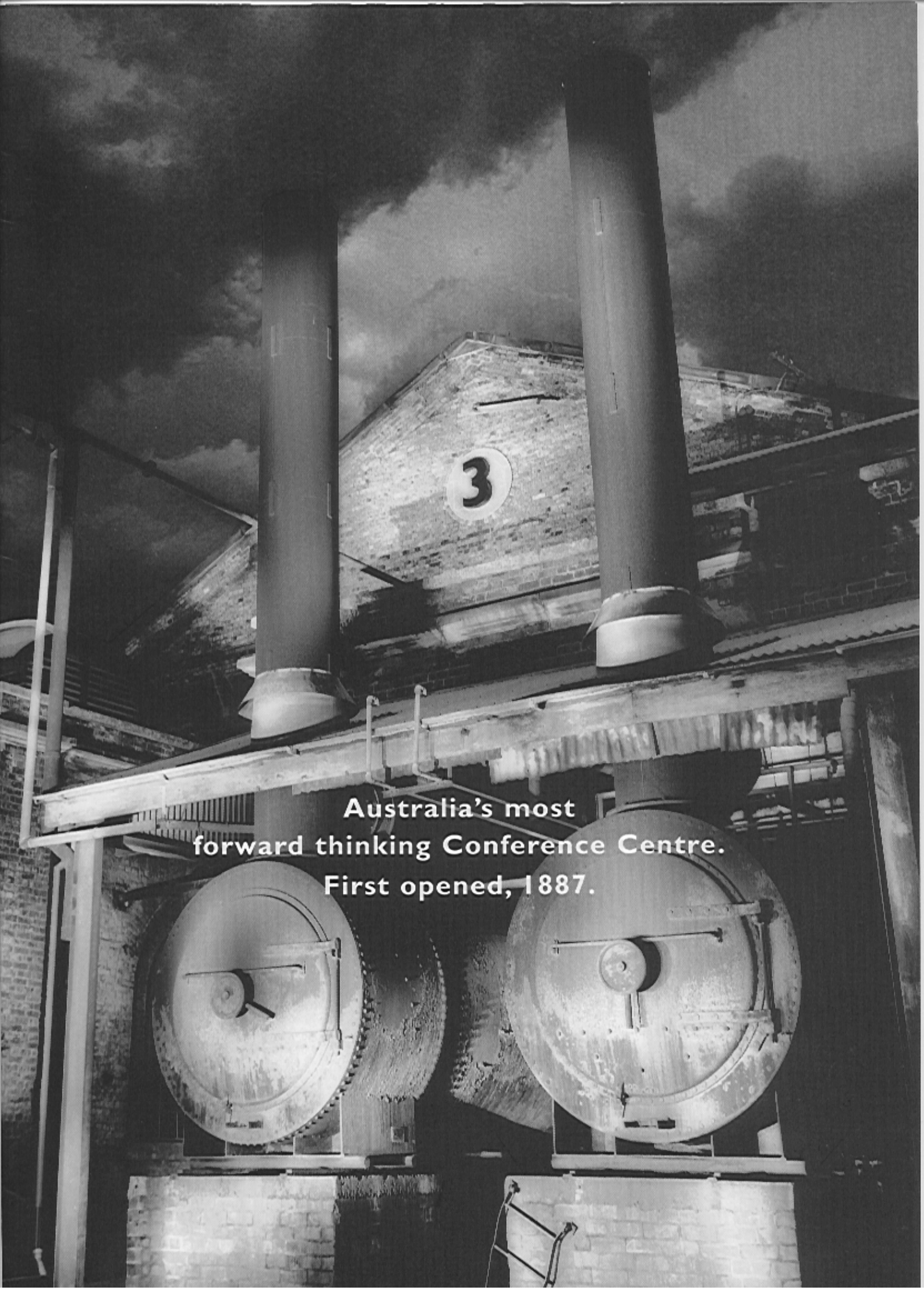

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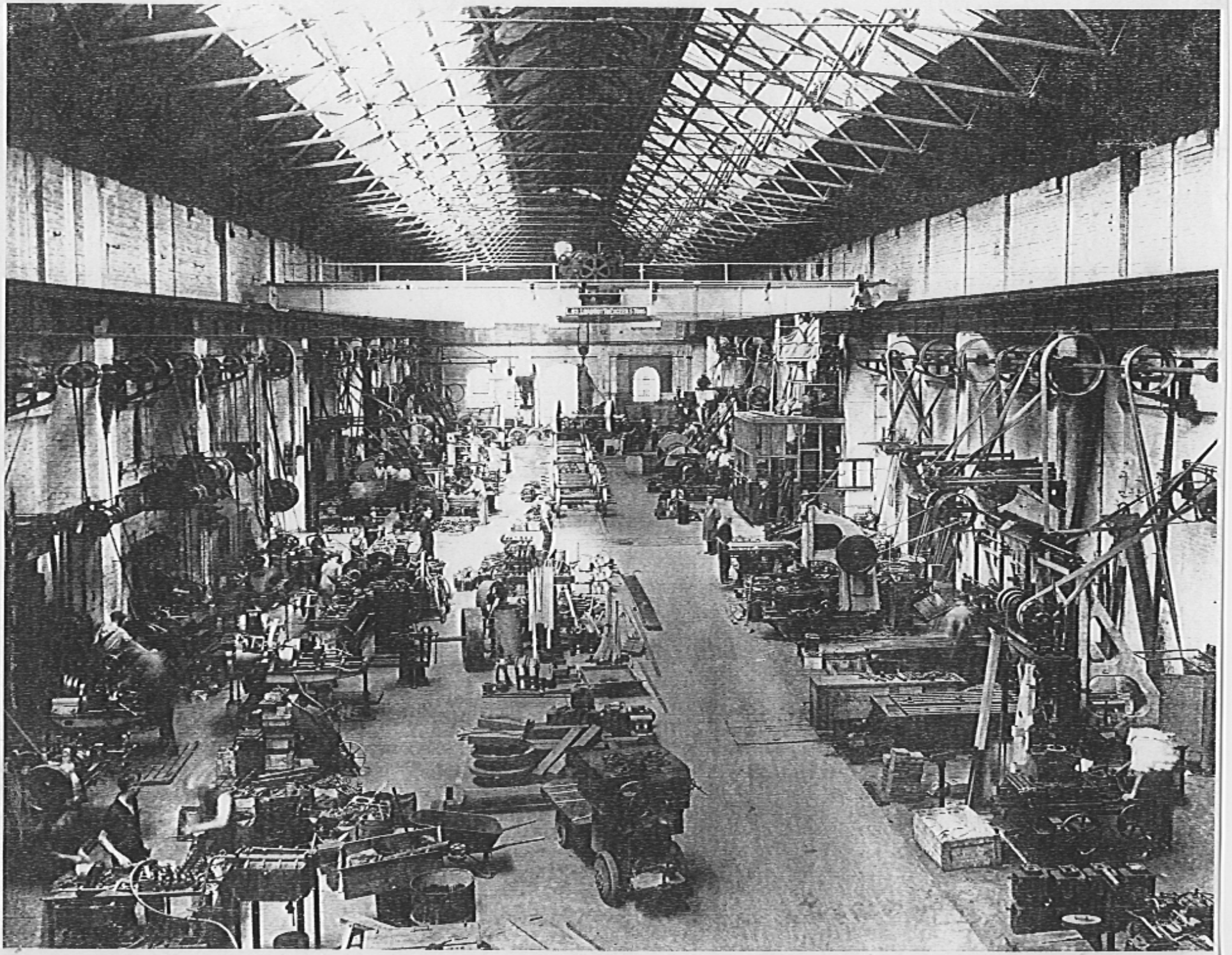

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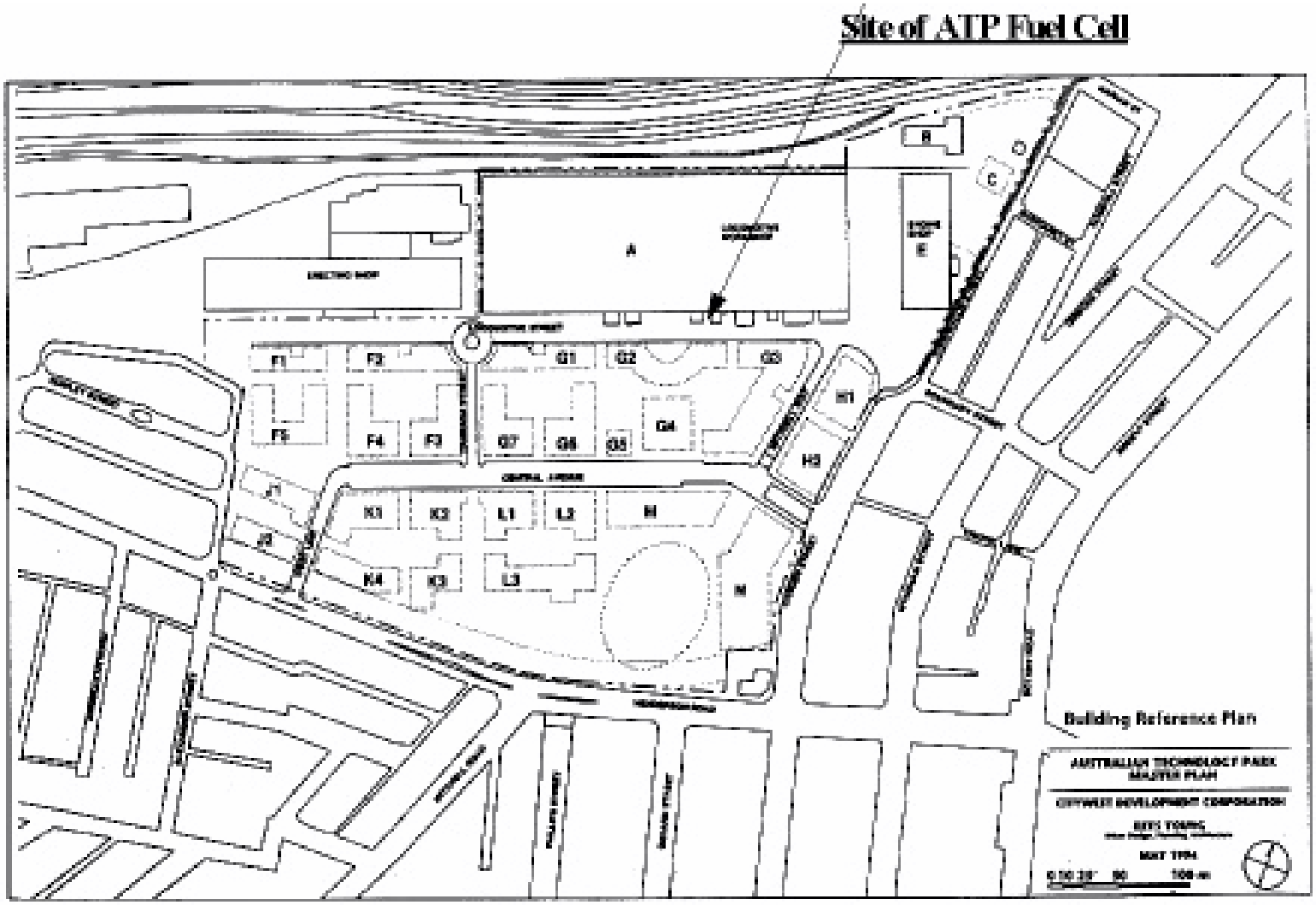


M **Site of Bio-Medical Building**

G3 **Site of Eco-Habitat Hotel**

PARK ENTRY CRITERIA

FOR THE AUSTRALIAN TECHNOLOGY PARK SYDNEY LIMITED

The Park Entry Criteria is the entry requirements which must be complied with for organisations wishing to locate at the ATP as listed below:-

(a) *Research, Development and Innovation*

- Research and development, or education intensive, measured by the proportion of turnover **generated at the ATP** which is spent on these activities. This is generally set at around **80%.**
- The approach taken by the ATP to the allowable activities on the Park revolves around the definition of what constitutes R&D. As with all our activities, our role is to be as flexible as we possibly can while maintaining our primary focus of developing a world class technology park. As such we generally describe the various activities to encompass, but not necessarily be limited to the following:-

Definitions	
Research:	The invention of new products, services, or processes
Development:	The refining of the invention, assessment of manufacturability, etc
Demonstration:	Prototype development, scaling-up of production, limited scale commercial operation[1]
Commercialisation:	Trial market testing, capitalisation of the business, development of marketing and distribution channels
Education:	Development and delivery of specific secondary, graduate and post graduate courses
Training:	Development and delivery of specific training programs

[1] It should be noted that for some product categories there is little difference between pilot operations and full scale commercial production. Such cases will be assessed on their individual merits.

- You must have a record of innovation, or a strong potential to establish such a record.

(b) *ATP Universities (desirable but not mandatory)*

- Existing relationship with one or more of the sponsoring universities, or a capacity and interest to build such a relationship.
- Technology focused on the Integrated Research Strengths of the participating universities or relevant to emerging technologies around which the sponsoring universities have expressed an intent to build expertise.

(c) *ATP Citizenship*

- Interest in and/or capability to participate in joint research and development projects with sponsoring universities and/or other park residents, or potential park residents.
- Interest in establishing linkages with other park residents; and in sharing non-proprietary, non-competitive information and resources with other park residents.
- Preparedness to contribute to an ATP operated data base of key issues, outcomes, personnel, and methodologies used to promote the tenant and the ATP nationally and internationally.
- Preparedness to participate in ATP sponsored functions wherein results of developments and dissemination of information across technology disciplines is the primary focus, intended for the park community.

- A preparedness to make use of park-provided services and facilities where appropriate, in order to generate a sense of community and cohesion within the park.
- Predisposition towards the use of Australian resources in manufacturing or human resource requirements.

(d) *Environmental Sustainability*

- Non-polluting, or demonstrated capacity to contain pollution and sympathy towards ecologically sound practices.
- A positive approach to, and support for energy management and conservation.

(e) *Education*

- Interest in shaping educational curriculum, and preparedness to participate in formal education skills based programs to promote technological involvement in industry.

(f) *Marketing*

- Willingness to credit the ATP where appropriate in written or other submissions to promote the ATP as a centre of pre-eminent development and research.
- Commitment to contribute in a meaningful way to a newsletter (in written, electronic, or other form) published by the ATP from time to time for local, national or international distribution.
- Interest in maintaining and enhancing the park's reputation and image.
- Interest in marketing the park, including welcoming park visitors (by appointment).
- Interest in facilitating the attraction of other organisations to the park, particularly those where a relationship already exists.
- Acceptance that "Australian Technology Park" will form part of the address of the tenant

(g) Occupational Health and Safety

- All Stakeholders at the ATP must comply with the ATP management Policy on Occupational Health and Safety.

(h) Environmental

- All stakeholders are to comply with the ATP management policy on Environmental issues and not carry out any activities that would adversely impact on that policy or on the health and safety of other stakeholders and the local community.

IMPERIAL TO METRIC CONVERSION

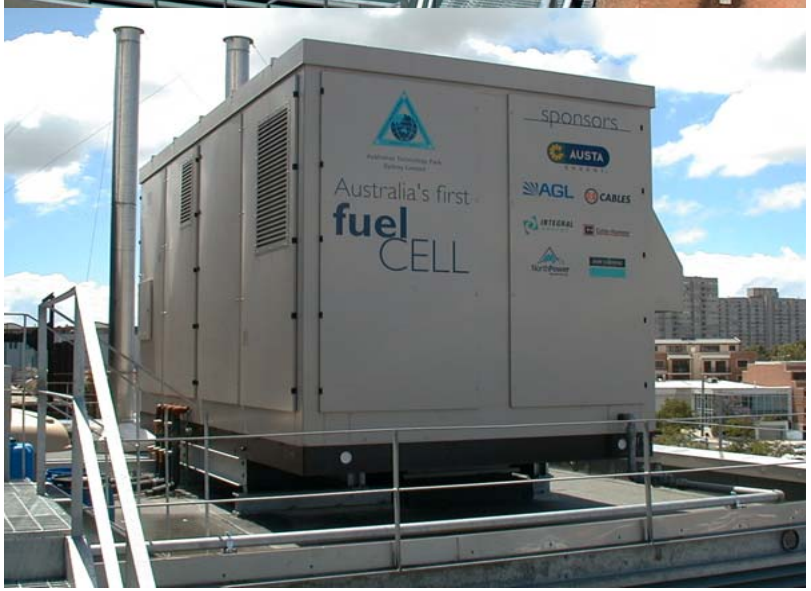
Quantity	Imperial Unit	Metric Unit	Conversion Factors (approx.)	
			Imperial to metric	Metric to Imperial
Length	inch (in)	millimetre (mm)	1=25.4	1=0.393701
	foot (ft)	centimetre (cm) or metre (m)	1=30.5cm	1cm= 0.393701 1m=3.28084ft
	yard (yd)	metre (m)	1=0.9144	1=1.09
	mile (m)	kilometre (km)	1=1.61	1=0.621
Mass	ounce (oz)	gram	1=28.3	1=0.353
	pound (lb)	kilogram	1=0.45359	1=2.20462
	stone	kiolgram	1=6.35	1=0.157
	ton	tonne	1=1.016	1=0.984
Area	square inch (1in^2)	square centemetre (cm^2)	1=6.45	1=0.155
	square foot	square centemetre (cm2)	1=929	1=0.001076
	square yard (yd^2)	square metre (m^2)	1=0.836	1=1.196
	acre	hectare	1=0.405	1=2.47
	square mile	square kilometre	1=2.59	1=0.386
Volume	cubic inch (in^3)	cubic centimetre (cm^3)	1=16.4	1=0.061
	cubic foot (ft^3)	cubic metre (m^3)	1=0.0283	1=35.3
	cubic yd (yd^3)	cubic metre (m^3)	1=0.765	1=1.31
	bushel	cubic metre (m^3)	1=0.0364	1=27.5
	fluid ounce (fl oz)	milliletre (ml)	1=28.4	1=0.0352
	pint (pt)	litre (l)	1=0.568	1=1.76
	gallon (gal)	litre (l) or cubic metre	1=4.55litre	1 m^3=220gal.
	acre foot	cubic metre (m3) or megalitre (Ml)	1=1230M^3 0r 1.23 Ml	1Ml=0.811 acre foot
Pressure	pounds per in^2 (psi).	Kilopascals	1=6.89	1=0.145
		mm of Mercury	1=750.061	1=0.001333
		inches of water	1=27.68	1=0.036127
		atmospheres	1=0.06805 atm	1=14.69508
	atmosphere (atm)	kilopascal (kpa) or mega pascals (mpa)	1=101kpa	1mpa=9.86923 atm
	ton per in^2	mega pascals	1=15.4	1=0.0647
	inch (in) of mercury (inHg)	millibar (mbar)	1=33.9 mbar	1=0.0295
			1mbar =100 Pa	1=0.001
			1 mbar =0.0145038 (psi)	1=68.9474
Temperature	Fahrenheit	Celsius ^oC	^oC=5/9(^oF-32)	^oF=9^oC/5 + 32
Energy	British Thermal Unit (Btu)	Kilojoule (kJ)	1=1.06	1=0.948
	Therm	megajoule	1=106	0.00948
	Electrical (kW)	megajoule	1=3.60	0.27778

Fuel Cell Installation

Arrival of Fuel Cell to ATP

Fuel Cell Foundations

Fuel Cell Installation



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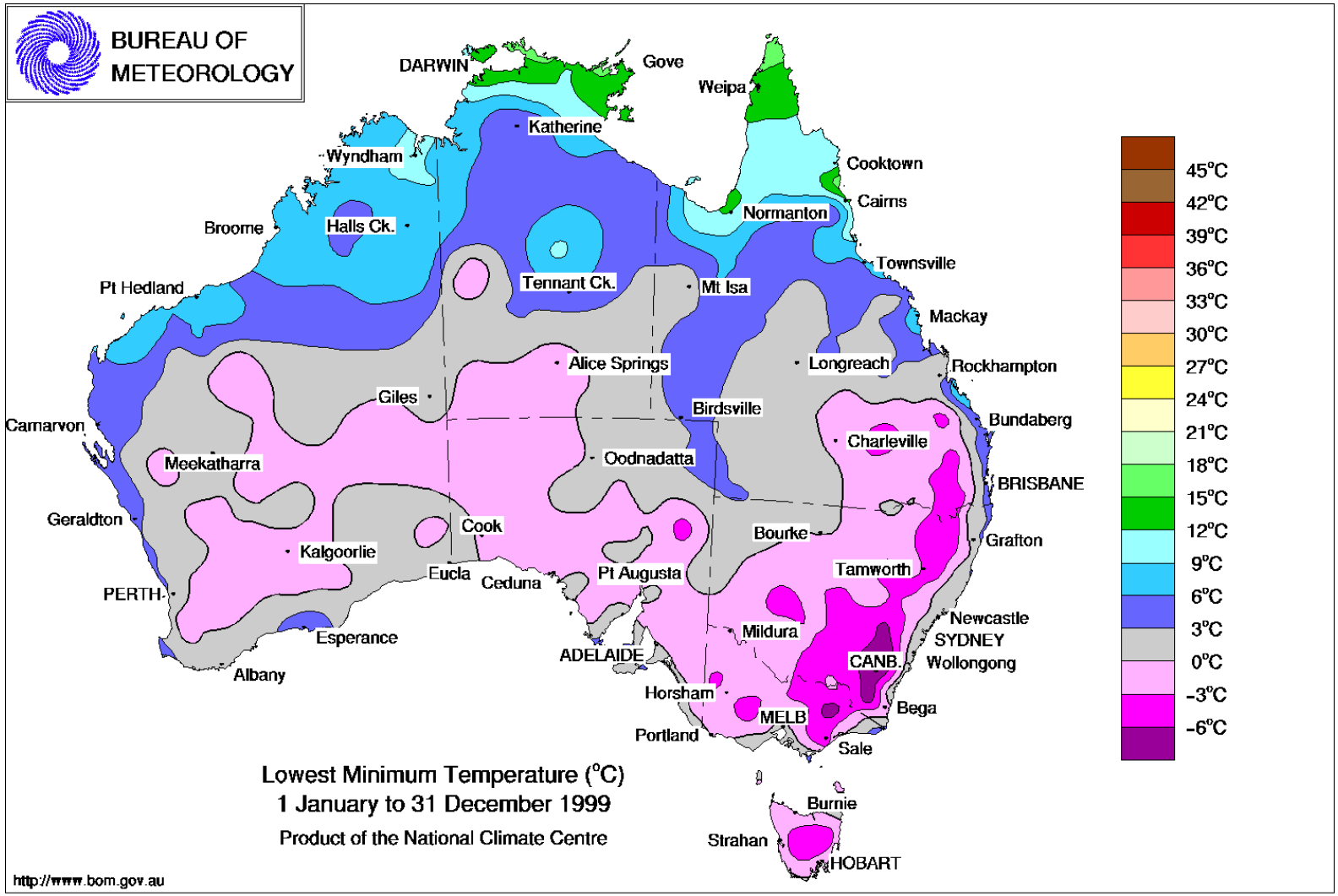
Installation

Metrology Data in Australia



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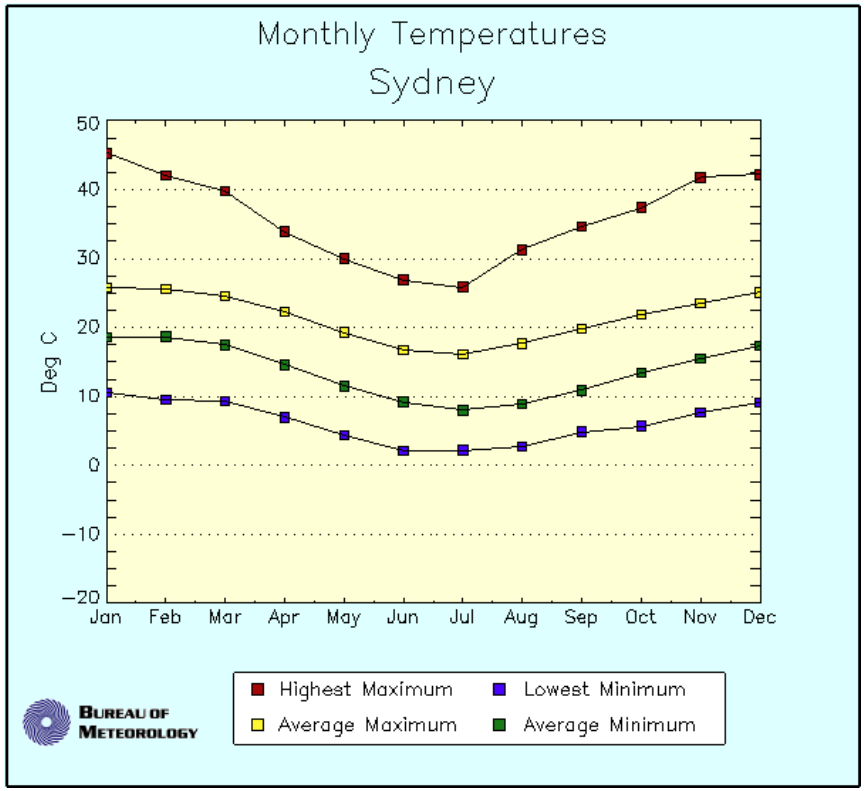
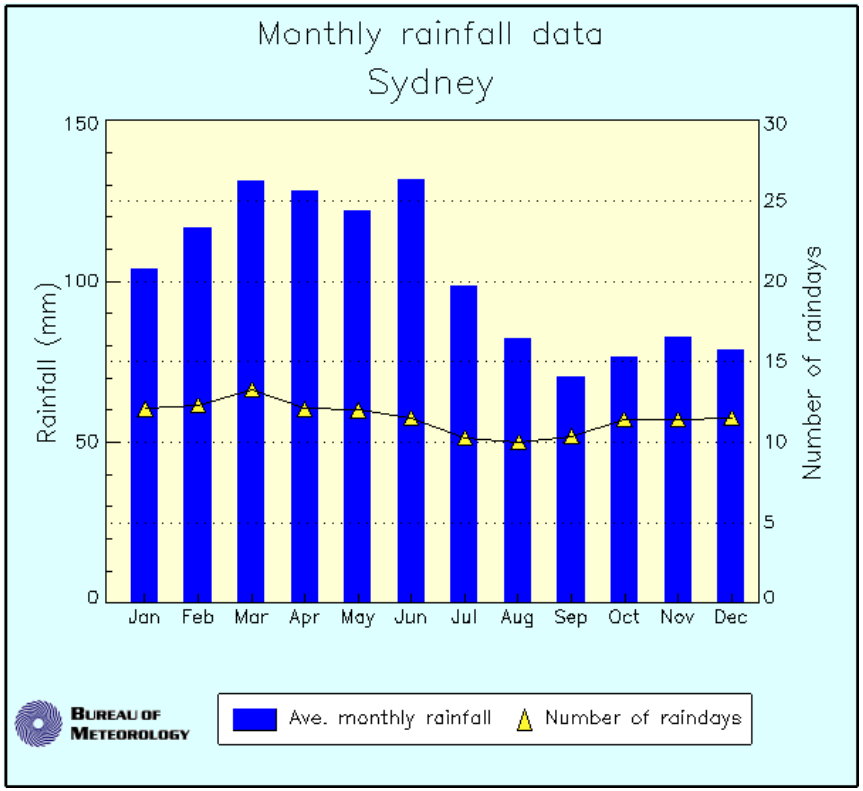
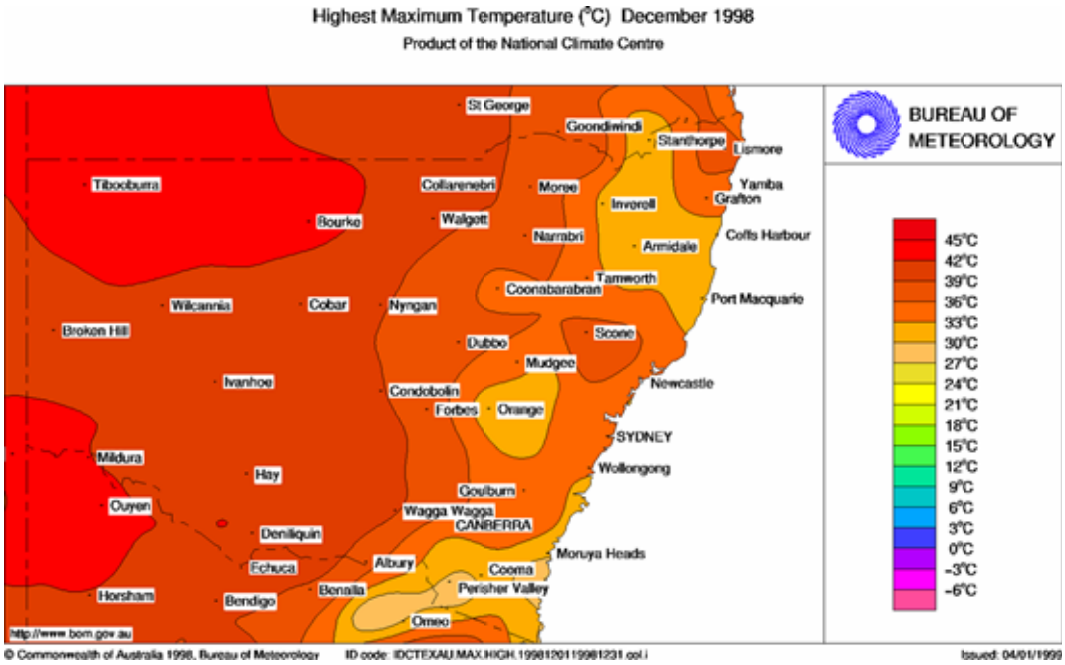
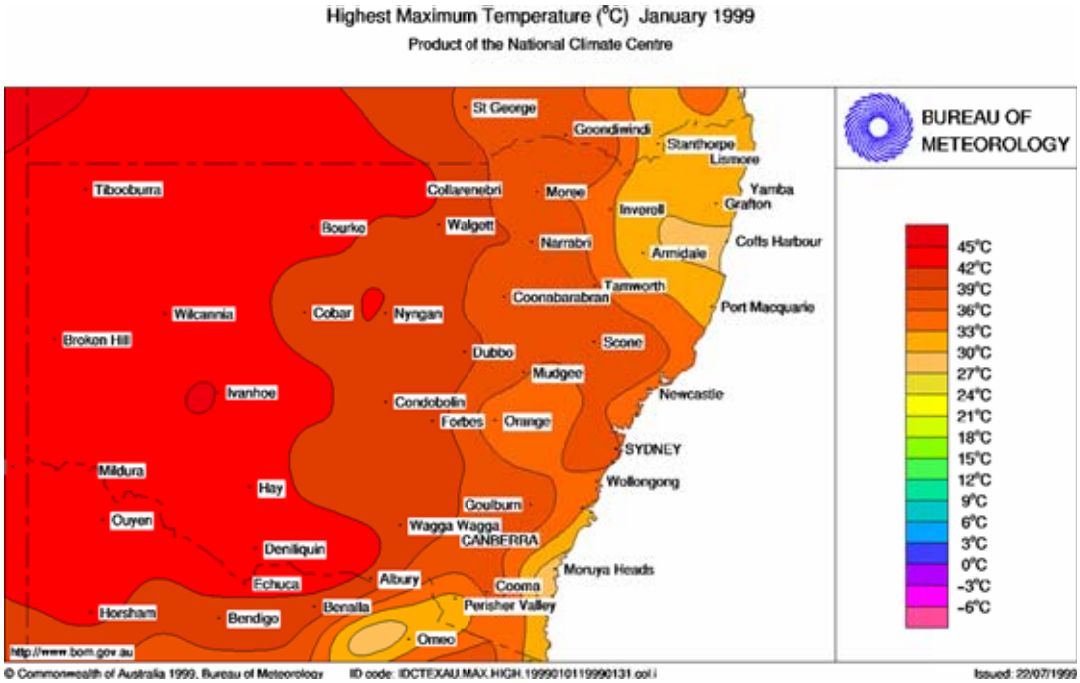
Temperature & Rainfall Data in Sydney





Summer Temperatures
Sydney Summer Months December - February





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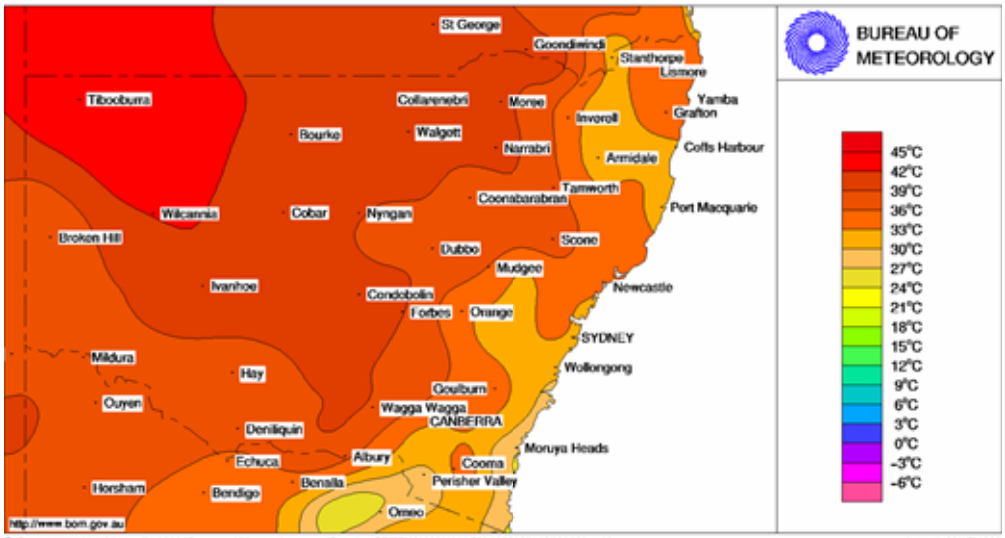
Summer Temperatures
Sydney Summer Months December - February

Highest Maximum Temperature (°C) February 1999

Product of the National Climate Centre



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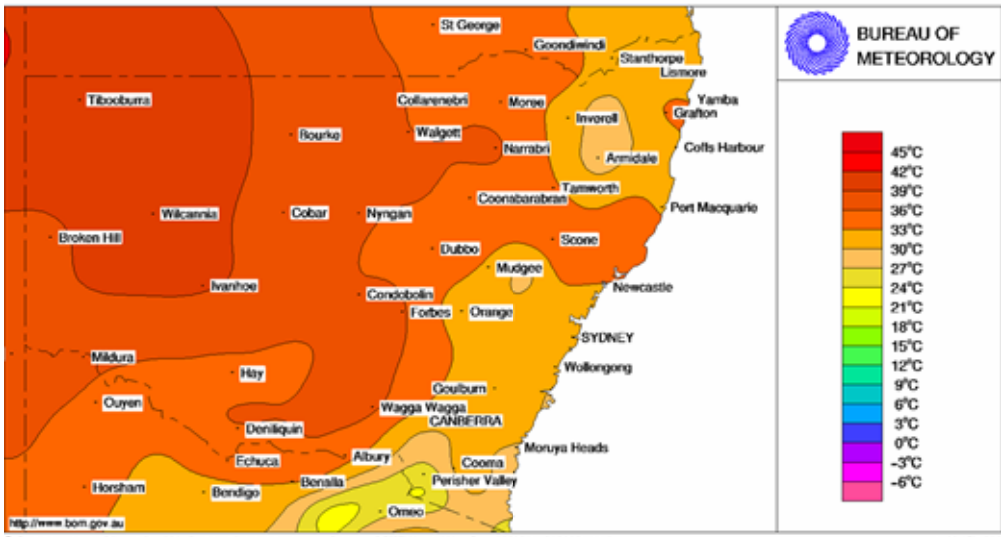
Highest Maximum Temperature (°C) March 1999

Product of the National Climate Centre



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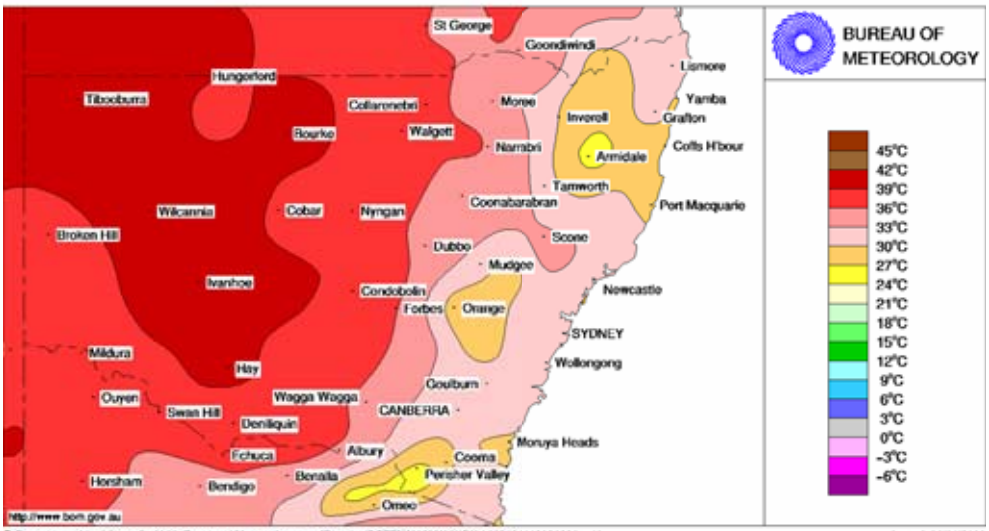
Summer & Winter Temperatures
Sydney Summer Months December - February

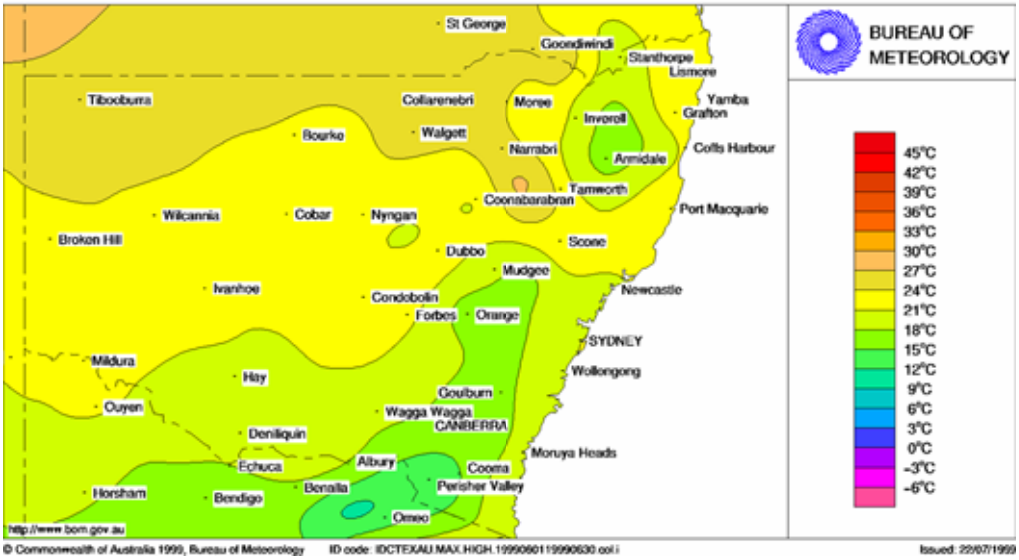
Highest Maximum Temperature (°C) December 1999

Product of the National Climate Centre



Highest Maximum Temperature (°C) June 1999

Product of the National Climate Centre



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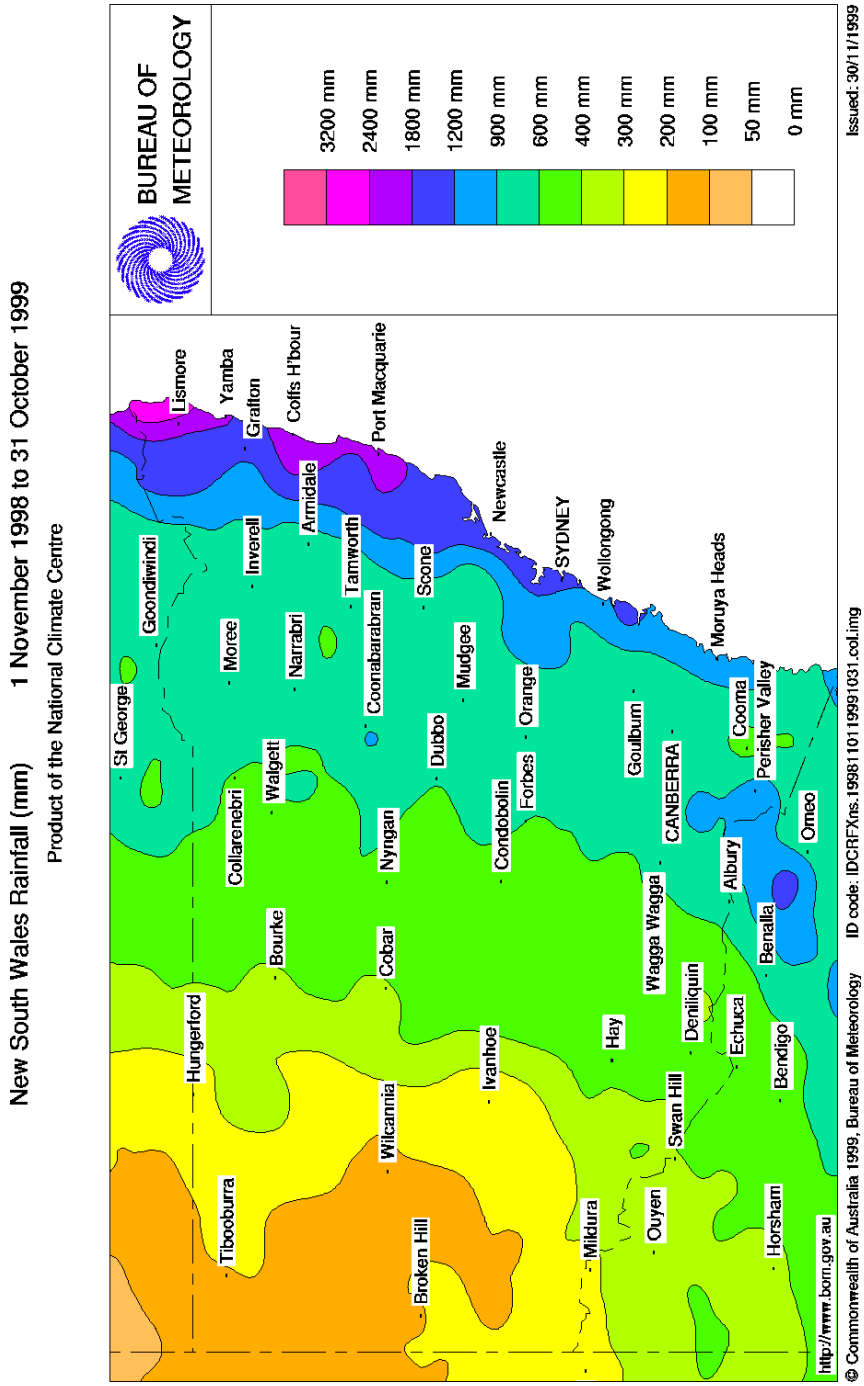
Rain During First Year of Fuel Cell Operation



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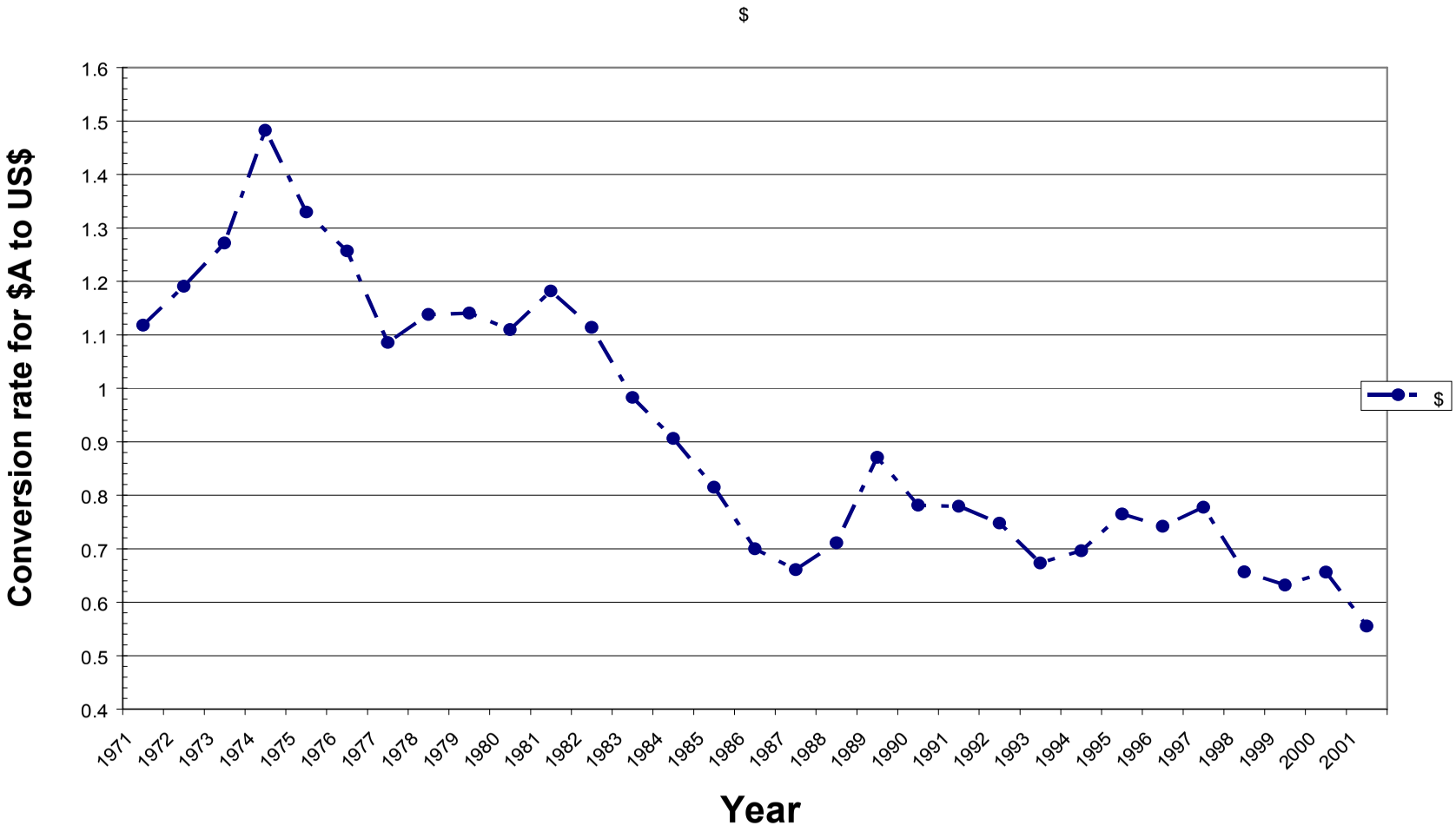
Australian to US $ Conversion Rates



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Certification Certificate from Gas Supplier for ATP Fuel Cell Installation

AGL

APPLIANCE APPROVAL CERTIFICATE

LOCATION NAME: AUSTRALIAN TECHNOLOGY PARK.

ADDRESS: GARDEN STREET, EVELEIGH.

APPLIANCE DESCRIPTION: ONSI PC25 C FUEL CELL.

APPLIANCE NUMBER: 2000-0032.

APPLIANCE INSTALLER: ONSI CORPORATION.

COMMISSIONING AGENT: ONSI CORPORATION.

The above appliance has been inspected and tested for compliance with AGL Gasfitting Rules.

The appliance was found to comply with the requirements current at the date of inspection.

If this appliance is modified or relocated, it shall be upgraded to meet the requirements of Gasfitting Rules current at the time of modification or relocation and be resubmitted to the Gas Authority for approval.

Whilst the Gas Authority has tested the appliance for compliance with the Gasfitting Rule requirements, the Gas Authority cannot accept responsibility for any failure to detect breaches of the requirements or for any inadequacies of the requirements.

Authorising Officer MARK STANLEY I.D. No. 326 Date 21-1-00

Centre INDUSTRIAL INSPECTION. ALEXANDRIA.

ESSENTIAL MAINTENANCE

This appliance and its safety equipment must be maintained in a state of proper repair. Failure to do so may render the appliance unsafe and liable to disconnection from the gas supply

AGL Gas Networks Limited A.C.N. 003 004 322 AGL Gas Company (ACT) Limited A.C.N. 008 552 663

COPIES: 1-Customer 2-Contractor 3-Book

95 4305 8.99

Australian Technology Park Fuel Cell Gas Supply Data.

FUEL	Gross or Higher Heating Value MJ per m^3	Net or Lower Heating value MJ per m^3	Ave.% in Sydney Natural Gas	N.G. Gross or Higher Heating Value MJ per m^3	N.G. Net or Lower Heating value MJ per m^3
Carbon Monoxide	11.971	11.97	0	0.00	0.00
Ethane	65.994	60.43	9.525	6.29	5.76
Ethylene	59.72	55.96	0	0.00	0.00
Methane	37.659	33.95	86.632	32.62	29.41
Propane	93.916	86.42	0.258	0.24	0.22
Propeylene	87.09	81.45	0	0.00	0.00
N-Butane	121.88	112.41	0.026	0.03	0.03
Iso Butane			0.015		
N-Pentane	149.605		0.007	0.01	0.00
Iso Pentane			0.006		0.00
Neo Pentane			0		0.00
Hexane+			0.017		0.00
Carbon Dioxide	0	0	2.609	0.00	0.00
Nitrogen	0	0	0.905	0.00	0.00
Total			100.00	39.20	35.42

Actual Gas Analysis September 2000

FUEL	Gross or Higher Heating Value MJ per m^3	Net or Lower Heating value MJ per m^3	% in ATP Natural Gas Fuel	N.G. Gross or Higher Heating Value MJ per m^3	N.G. Net or Lower Heating value MJ per m^3
Carbon Monoxide	11.97	11.97	0	0.00	0.00
Ethane	66.06	60.43	7.8	5.15	4.71
Ethylene	59.72	55.96	0	0.00	0.00
Methane	37.71	33.95	88.8	33.49	30.15
Propane	93.94	86.42	0.2	0.19	0.17
Propeylene	87.09	81.45	0	0.00	0.00
N-Butane	121.8	112.41	0	0.00	0.00
N-Octane	233.29	216.38	0	0.00	0.00
Carbon Dioxide	0	0	1.9	0.00	0.00
Nitrogen	0	0	1.3	0.00	0.00
Total			100.00	38.83	35.03

Typically 1.5 mg/m^3 Mercaptan Sulphur, 1.0 mg/m^3 Hydrogen Sulphide, Odorant (as Specified) 6.0 mg/m^3, Total Sulphur (all sources) 8.5 mg/m^3. The total levels are expressed in terms of the sulphur component only,(the odorant mix as used is 36% sulphur by weight). AGL advise also that the gas contains 112.01.5 mg/m^3.

The Specific Energy is the heat obtained by th complete combustion of a unit of gas(quantity of fuel) and is normally expressed as megajoulesperkilogram for solid and liquid fuels i.e. MJ/Kg and as megajoules per M3 for gases i.e. MJ/M3.

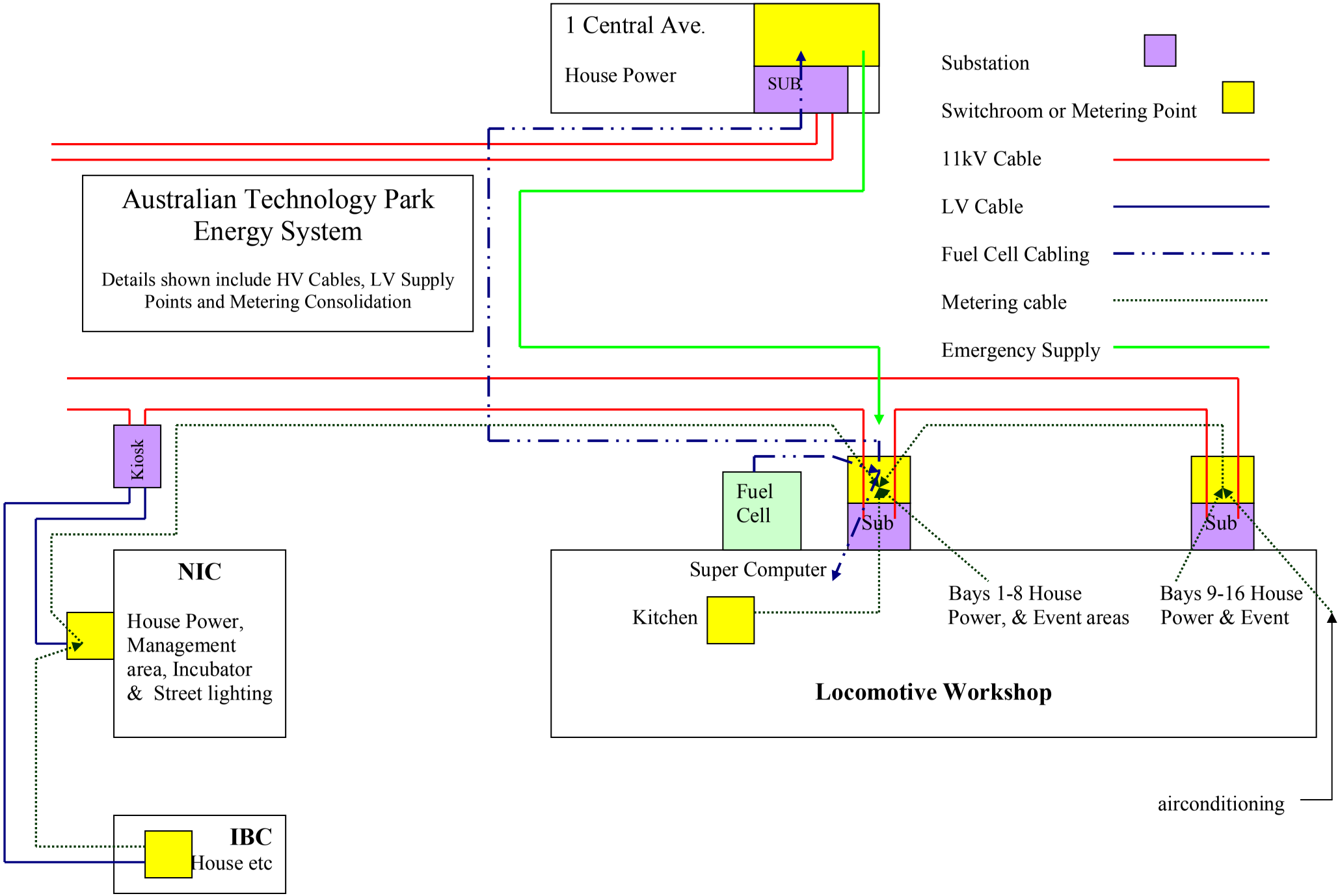
The Gross or Higher Heating value is obtained when all products of combustion are cooled to room temperatureand the latent heat of vaporisation of water recovered.

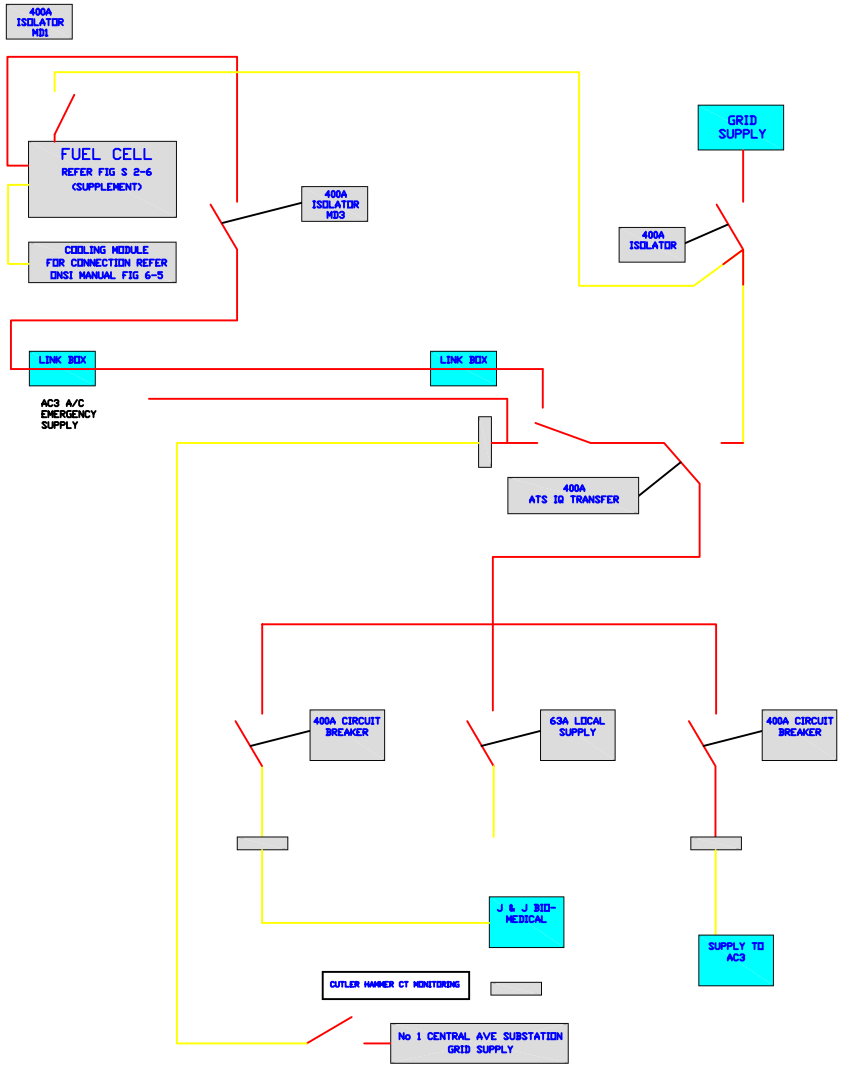
The Net or Lower Heating value is obtained when the water vapour is not condensed.

The Gas supplied to the ATP is Natural Gas and is measured by the AGL in cubic metres with a pressure and composition correction factor. AGL advise that the Gross (Higher) Heating Value of 38.8 MJ/M3 and a Net (Lower) Heating Value of 35 i.e. in line with the above data.

Fuel Cell Operational Data Summary for 700 Days of Operation

INPUT DATA		Total Service	Total 1998/99 i.e. from 4/11/98	Total 1999/2000	Total 2000/01 to 15/07/01
Gas	M^3	696684	78803	324687	293194
	GJ (LHV)	24404.8	2760.5	11373.8	10271
OUTPUT DATA					
Electrical	kWHr	2713938	296200	1271800	1145938
Thermal	GJ	0.00	0.00	0.00	0.00
EFFICIENCY (LHV)	%	40.03	38.63	40.25	40.22
Green House & other Emission Reduction.	tonnes	2065.04	225.98	967.72	871.34
Operational Time	Days	700.38	98.91	316.30	267.00
Operational % with discretionary shutdown time excluded		95.72	89.11	96.44	94.37


1 Central Ave.
House Power
SUB
Substation
Switchroom or Metering Point
11kV Cable
LV Cable
Fuel Cell Cabling
Metering cable
Emergency Supply
Australian Technology Park
Energy System
Details shown include HV Cables, LV Supply
Points and Metering Consolidation
Kiosk
Fuel
Cell
Sub
Sub
NIC
House Power,
Management
area, Incubator
& Street lighting
Super Computer
Kitchen
Bays 1-8 House
Power, & Event areas
Bays 9-16 House
Power & Event
Locomotive Workshop
airconditioning
IBC
House etc



AUSTRALIAN TECHNOLOGY PARK
Sydney Limited ACN 060 969 119
Suite 145 National Innovation Centre
Australian Technology Park, EVELEIGH
NSW 1430, AUSTRALIA
Email: atp@atp.com.au
URL: http://www.atp.com.au

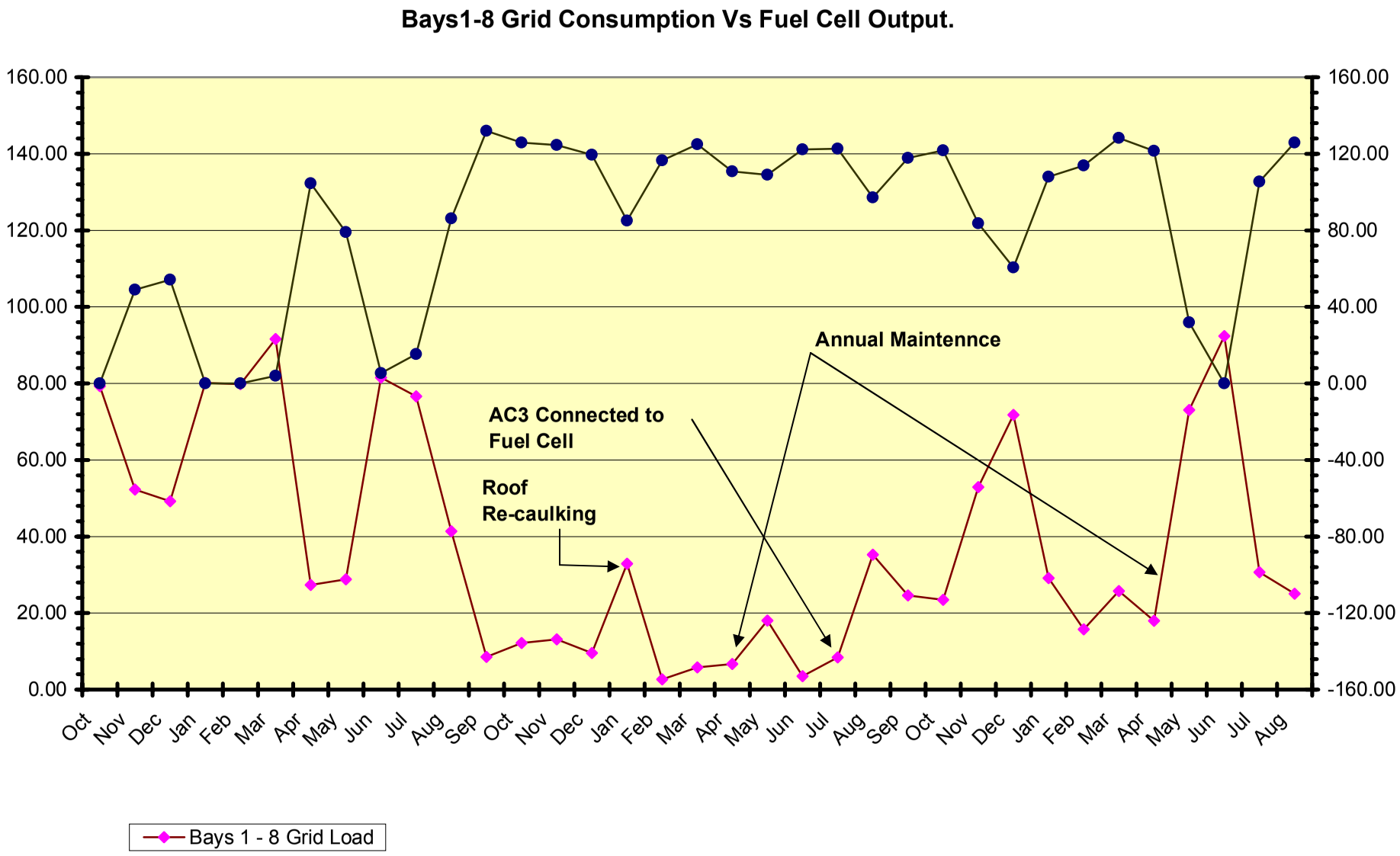
SINE INDUSTRIES PTY LTD
ELECTRICAL, INSTRUMENTATION & CONSTRUCTION SERVICES
ABN 95 060 051 934
PH: 61 2 9807 7834
FAX: 61 2 9807 7832
EMAIL: sine@sine.com.au

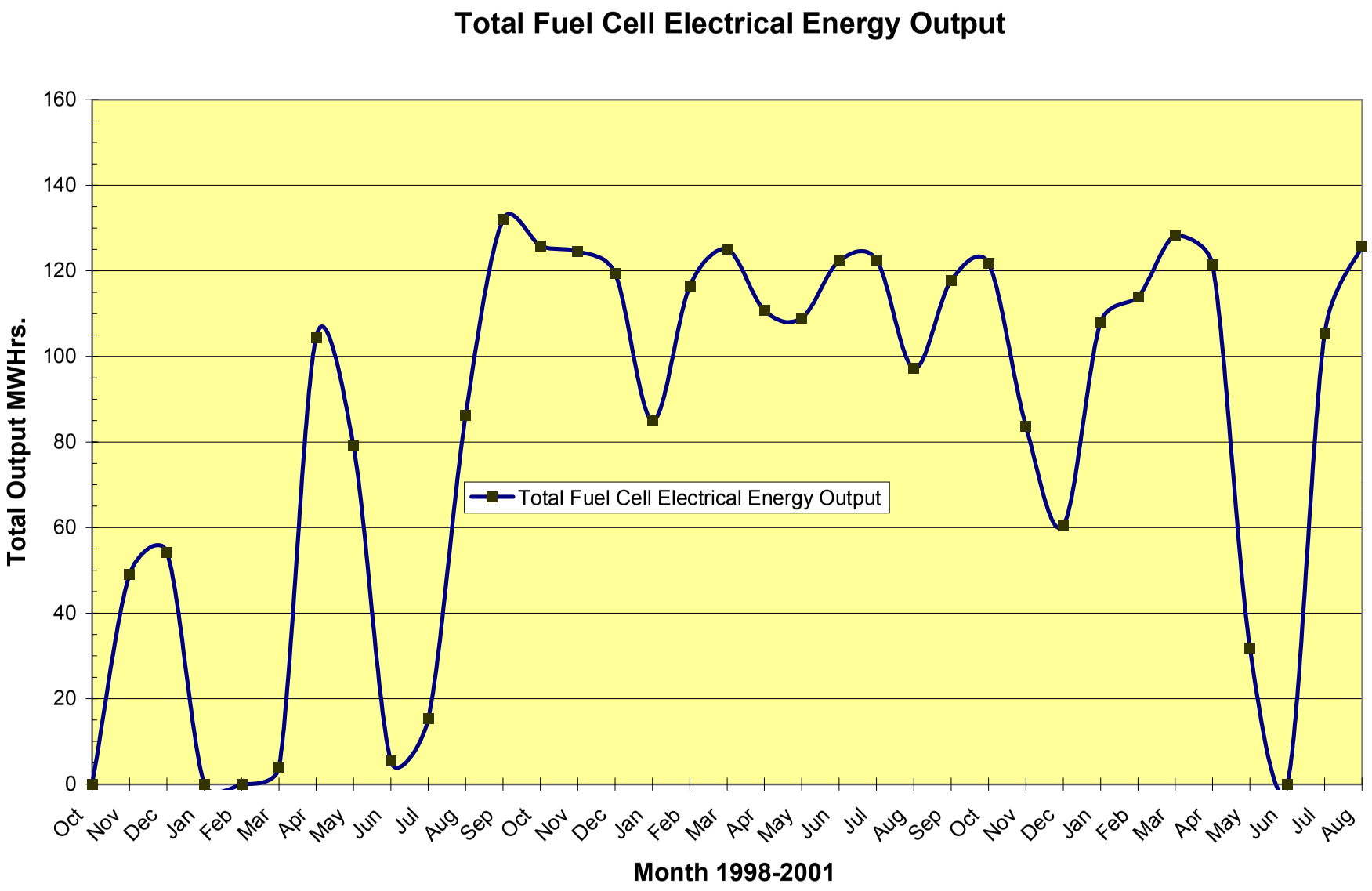
Brian Jay
Strategic Energy Development
5 Maybrook Ave
Cromer Hts.
NSW Australia 2099
ABN 99078 128 820

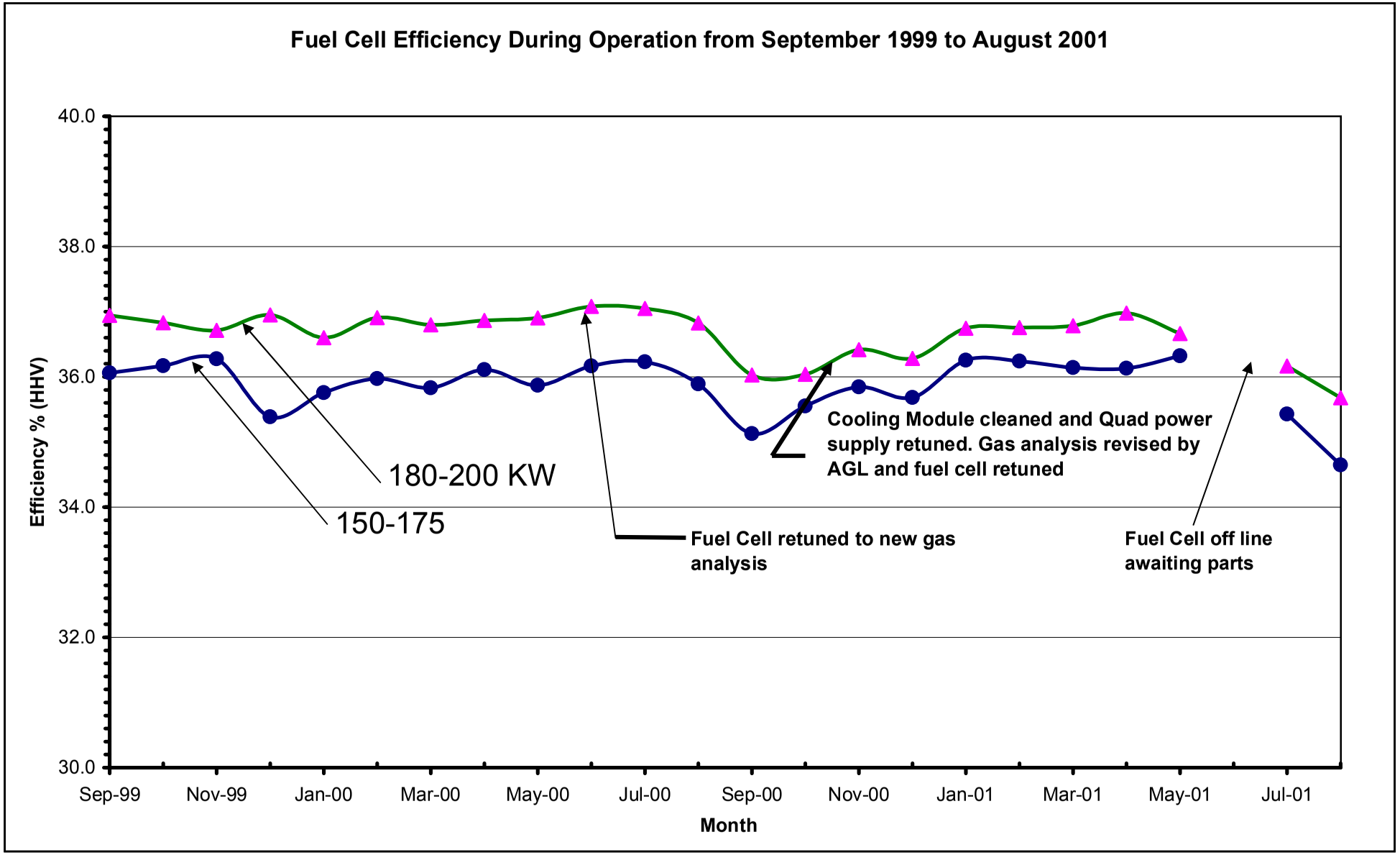
Australian Technology Park Precinct Management Ltd.
ABN 47- 060969119
Bay 8 Locomotive Workshop, Eveleigh
NSW 1430 Australia

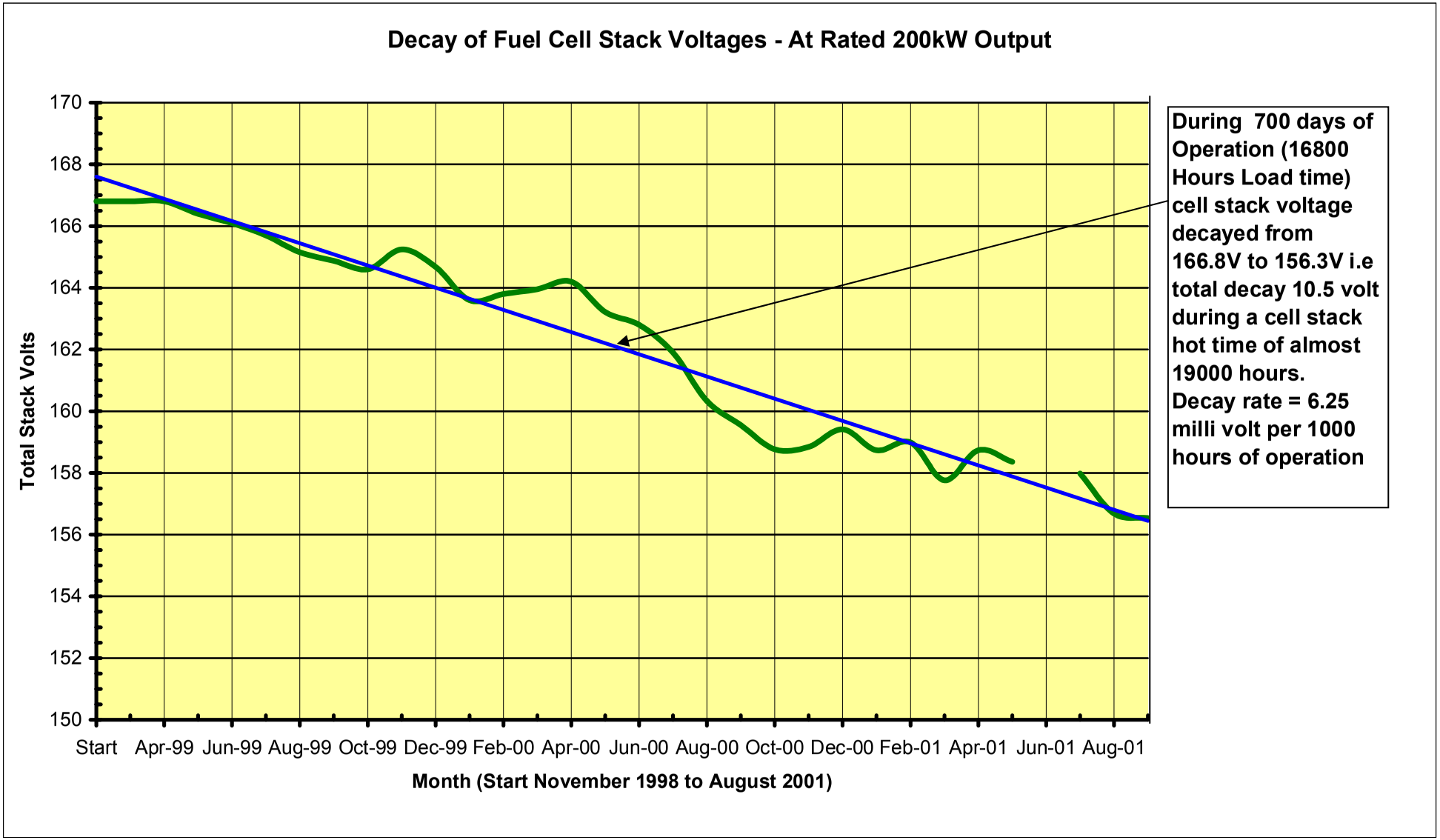
Grant Applicant & Project Sponsor | Project Director & Installation Designer | Australian Technology Park Owne

FUEL CELL AT THE AUSTRALIAN TECHNOLOGY PARK


Bays1-8 Grid Consumption Vs Fuel Cell Output.
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
160.00
120.00
80.00
40.00
0.00
-40.00
-80.00
-120.00
-160.00
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
Annual Maintennce
AC3 Connected to
Fuel Cell
Roof
Re-caulking
Bays 1 - 8 Grid Load


Total Fuel Cell Electrical Energy Output
Total Output MWHrs.
160
140
120
100
80
60
40
20
0
Total Fuel Cell Electrical Energy Output
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Month 1998-2001


Fuel Cell Efficiency During Operation from September 1999 to August 2001
40.0
38.0
36.0
34.0
32.0
30.0
Efficiency % (HHV)
Sep-99
Nov-99
Jan-00
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Month
180-200 KW
150-175
Fuel Cell retuned to new gas analysis
Cooling Module cleaned and Quad power supply retuned. Gas analysis revised by AGL and fuel cell retuned
Fuel Cell off line awaiting parts


Decay of Fuel Cell Stack Voltages - At Rated 200kW Output
Total Stack Volts
170
168
166
164
162
160
158
156
154
152
150
Start
Apr-99
Jun-99
Aug-99
Oct-99
Dec-99
Feb-00
Apr-00
Jun-00
Aug-00
Oct-00
Dec-00
Feb-01
Apr-01
Jun-01
Aug-01
Month (Start November 1998 to August 2001)
During 700 days of Operation (16800 Hours Load time) cell stack voltage decayed from 166.8V to 156.3V i.e total decay 10.5 volt during a cell stack hot time of almost 19000 hours.
Decay rate = 6.25 milli volt per 1000 hours of operation

Corrosion of Fuel Cell Housing

Rust In Door Corner of Ventilation Hood

Rust In Door Below Ventilation Hood

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Rust in Top of Doors

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Appendix

Publicity

Recognition of Project & Consortium Recognition

This was achieved by:-

•Article- The Australian Gas Journal Vol. 63 No1 April 1999.
•Article- The Australian Energy News Issue 6 Dec 1997.
•Article- The Australian Energy News Issue 6 Dec 1999.
•Article- The Australian Gas Light Co. Publication Issue 5 Summer 1998.
•Article – Integral Energy – staff publication.
•Article- Engineers Australia February 1999.
•Article- Ascent Technology Magazine November 1997.
•Article- Ascent Technology Magazine June 1999.
•Article – Business NSW November 5, 1999.
•Article – The Australian Newspaper July 14, 1998.
•Media Releases by ATP (3), Austa Energy (1) and NorthPower (1).
•Inclusion in the Australian Government "Greenhouse Challenge – Cool Solutions from Australian Business" publications as an example of ways to handle the Greenhouse issue.
•and NSW Governments on the ONSI Fuel Cell at the ATP.
•Exhibition in the Australian Parliament House on the ATP Fuel Cell installation. This exhibition incorporated material provided by ONSI.
•Prepared and produced for the Australian Gas Association Research Paper No.11. This publication is sold by the Association and covers all fuel cell technologies with a focus on the ONSI fuel cell at the ATP.
•Integral Energy and NorthPower issued a publication on the ATP fuel cell to their customers.
• Presentation to IE Aust Victorian Branch Joint Technical Meeting on Fuel Cells.
•3 Presentations at ESAA courses on the Fuel Cell. Brisbane, Sydney and Wollongong.
•Presentation to the Australian Gas Association Annual Conference, September 1999.
•Letters to the Australian

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00NT40773

ONSI Testimonies on ATP Project

It seems only a short time ago that I made the trip to Sydney to meet with Brian Jay and Dr. Tom Forgan to discuss the possibility of this project and review the specifics of the site and the application. Recognizing that this would be the first commercial fuel cell project in Australia, and in the Southern Hemisphere as well, the attributes of this site and application were immediately obvious-- a technology park dedicated to the demonstration and implementation of new technologies benefiting Australian business. And a team of individuals committed to the project, spear-headed by Brian Jay.

In short, we believed this was an ideal opportunity, and today's celebration (first year's operation function) is the proof. By way of example, one criteria we often use is the completeness of the installation process prior to our arrival for pre-start check-out and initial start-up of the units. This was one of the best, if not the best, prepared sites that our field technician had experienced…"

"Brian did a thorough job throughout the installation and start-up process, and continues to display his newly learned skills in the operation and maintenance of this power plant. We at ONSI appreciate his efforts in making this project a continuing success."

"…(Brian). You have provided excellent service to the power plant and are well trained in that area. It would not seem prudent to ignore that experience and availability if the desire is to maintain high power plant reliability and operability."

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00NT40773

AGA
Research
Paper No. 11

FUEL CELLS

Technologies and Opportunities

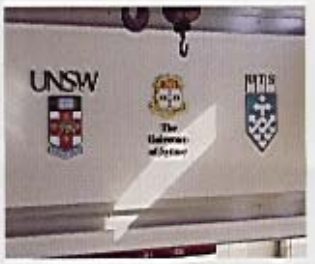
The
Australian Gas
Association

December
1999

INTEGRAL energy

WE THINK. WE'RE DIFFERENT.

Innovation in action – a working fuel cell at the ATP



A group of high technology industries, of which Integral Energy is a leading member, has acquired and installed the southern hemisphere's first commercial **fuel cell** at the Australian Technology Park (ATP).

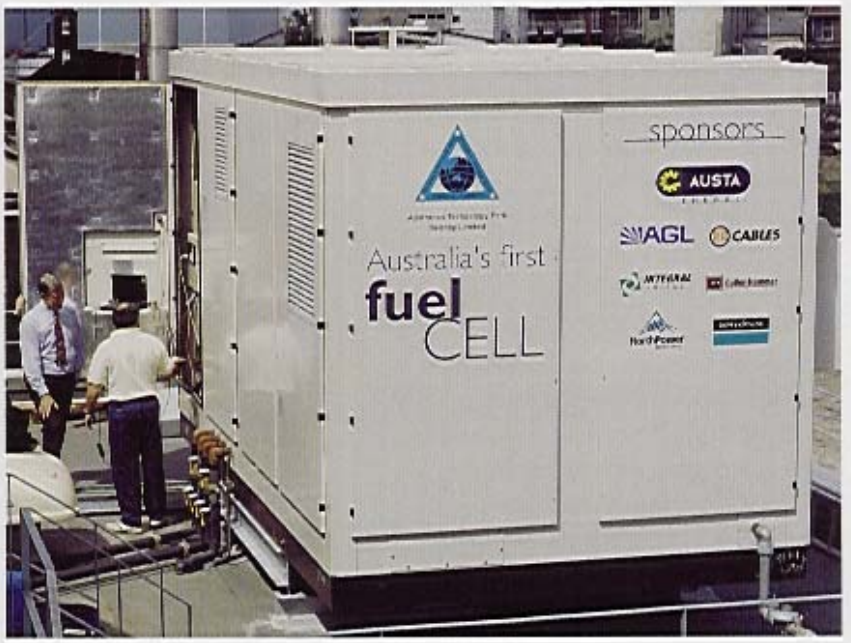
■ Configured as a 'cogenerator', the fuel cell converts natural gas into electricity and heat.

The 200kW (kilowatt) unit was built in the United States by the company that produces fuel cells for the National Aeronautics and Space Administration (NASA) – and is similar to the technology which is used to generate electricity and produce heat aboard the space shuttle.

Integral Energy has worked with the Australian Technology Park and other major partners to bring the fuel cell project to fruition – including Austa Energy, AGL and Northpower.

■ The ATP itself, located on the site of Sydney's historic Eveleigh locomotive works, has sprung from a vision that high technology industries, such as Integral Energy, together with The University of NSW, The University of Sydney, and The University of Technology Sydney, could gain mutual benefits from working together – not only sharing technology, but inspiring each other's innovation.

Eighty per cent of tenants at the ATP are engaged in research and development.



■ The fuel cell project is a valuable resource for the ongoing development of Integral Energy's expertise in viable and efficient, environmentally friendly energy sources.

■ Fuel cells have moved from the experimental stage to production technology. The practical application of the process at the ATP facilitates a wide ranging technical, environmental and financial evaluation of the potential for wider use in our community. The unit supplies electricity for the park's critical needs such as the biomedical building and heat for the hotel.

■ Greenhouse gas emissions from a fuel cell are very low. In fact, the exhaust air has been noted as cleaner than that of many major urban localities. The ATP unit itself will reduce greenhouse gas emissions in NSW by 1100 tonnes yearly.

■ Integral Energy's involvement with the innovative ATP fuel cell project is one component of our portfolio of commitment to the development of new sources of energy – and to the reduction of greenhouse gas emissions.

For more information

For technical and operational information see overleaf – or call the **Environmental Energy Manager** at Integral Energy on **131 081**

Fuel Cell

Technical and operational information

INTEGRAL energy

WE THINK. WE'RE DIFFERENT.

■ The remarkable fuel cell unit now in operation at the Australian Technology Park is the result of co-operation between **Integral Energy*** and other sponsors (see overleaf). It is a practical demonstration of an emerging source of 'clean' energy.

■ Fuel cell technology converts natural gas into electricity and heat through chemical action (see right).

■ While natural gas is normally used as the fuel source, the unit will operate on alternatives such as methane from landfill sites and digester gas from sewer systems.

■ The ATP unit will reduce greenhouse gas emissions in NSW by 1100 tonnes yearly. While CO_2 (carbon dioxide) is a by-product of a practical fuel cell, its production rate is less than conventional generation.

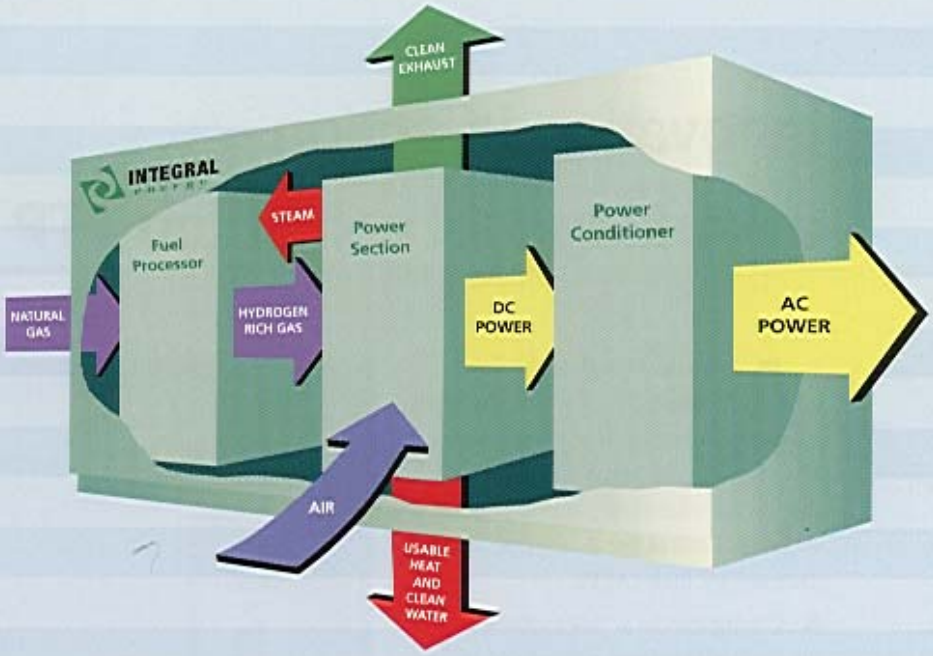
■ The cell's internal chemical reactions are similar to a battery and the output is DC (direct current). The current is proportional to the size of the electrodes, while the voltage is limited to the electrochemical characteristics of the electrodes. Individual cells are then 'stacked' until the desired power level is reached.

■ The DC output is processed by an inverter to produce AC (alternating current) power for grid or load connection.

■ The ATP fuel cell is configured as a cogenerator, producing 200 kilowatts (kW) of electricity and up to 220kW of potential hot water production.

■ Other operational benefits include:

- Low running costs from an operational efficiency of up to 80 per cent.
- Immunity to disruption of supply from storms and lightning.
- Noise output is very low.



The fuel cell concept –

Basic fuel cell	The basic fuel cell electrochemically combines H_2 and O_2 to release electrical power, heat and water.
Anode	H_2 is introduced to the anode where it is oxidised. $2H_2 \rightarrow 4H^+ + 4e^-$
Electrolyte	Hydrogen ions transfer from the anode through the electrolyte to the cathode.
Cathode	O_2 is introduced to the cathode, where it is reduced. $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$ + heat. The cathode releases water and heat.

The practical fuel cell –

It is not practical or economical to use pure hydrogen and oxygen in fuel cells. Practical fuel cells derive their hydrogen from hydrogen rich gases such as natural gas (methane CH4). The oxygen is derived from air. The only variation to the chemical reaction is that natural gas is processed before use in the fuel cell.

$$CH_4 + 2H_2O(\text{steam}) \rightarrow 4H_2 + CO_2$$

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Australia's Technology Park generates alternative energies

Australia's first fuel CELL

Once the exclusive domain of NASA spaceships, fuel cell technology has returned to earth — providing efficient, low emission, 'green' energy to Australia's Technology Park (ATP) at Everleigh in Sydney.

Once the exclusive domain of NASA spaceships, fuel cell technology has returned to earth – providing efficient, low emission, 'green' energy to Australia's Technology Park (ATP) at Eveleigh in Sydney.

The first of its kind in the southern hemisphere, the fuel cell project has been jointly sponsored by NorthPower and a consortium of high technology industries.

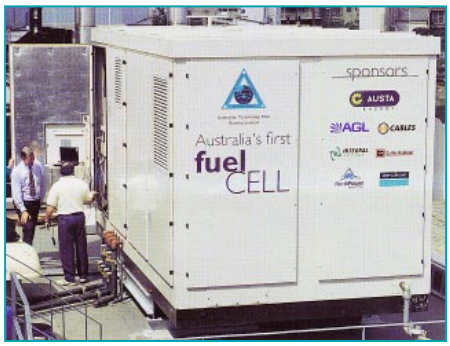
Roughly the size of a railway shipping container and able to supply energy to entire shopping centres and factories, fuel cell technology has important implications for the ongoing development of environmentally friendly energy sources.

Operating almost in the same way as a household battery, fuel cells do not have moving parts and chemically convert natural gas into electricity and heat. Unlike batteries, fuel cells do not run down or require recharging.

As a result, fuel cells can dramatically decrease coal-fired generation and oil usage, increase fuel use efficiency, lower greenhouse gas emissions and reduce operating costs at the same time as providing immunity from disruption to grid-type energy supply.

The ATP fuel cell produces 200 kilowatts (kW) of electricity and up to 220kW of potential hot water production. While carbon dioxide is a by-product of the cell, its production rate is less than conventional generation and the exhaust air is cleaner than that of many major urban localities.

NASA used the technology to generate electricity and heat aboard the space shuttle, facilitating wide-ranging technical, environmental and financial applications of fuel cell technology in the wider community.



Caption

Not surprisingly, the ATP Fuel Cell has generated considerable interest in Australia with development moving from the experimental stage to production technology.

NorthPower's partners in the project include Austa Energy, AGL, Cables, Integral Energy, Dow Corning and Cutler-Hammer with support from ATP participants – the University of NSW, the University of Sydney and the University of Technology.

Technical and operational specifications are provided overleaf.

Australian Technology Park Sydney Limited

Call NorthPower's
Product Development Officer,
Dennis Stanley on (02) 6582 8777.

NorthPower
Service with Energy!

Australia's first fuel CELL

Technical and operational information

The fuel cell concept

Basic fuel cell

The basic fuel cell electrochemically combines H_2 and O_2 to release electrical power, heat and water.

Anode

H_2 is introduced to the anode where it is oxidised.

$2H_2 \rightarrow 4H^+ + 4_e^-$

Electrolyte

Hydrogen ions transfer from the anode through the electrolyte to the cathode.

Cathode

O_2 is introduced to the cathode, where it is reduced.

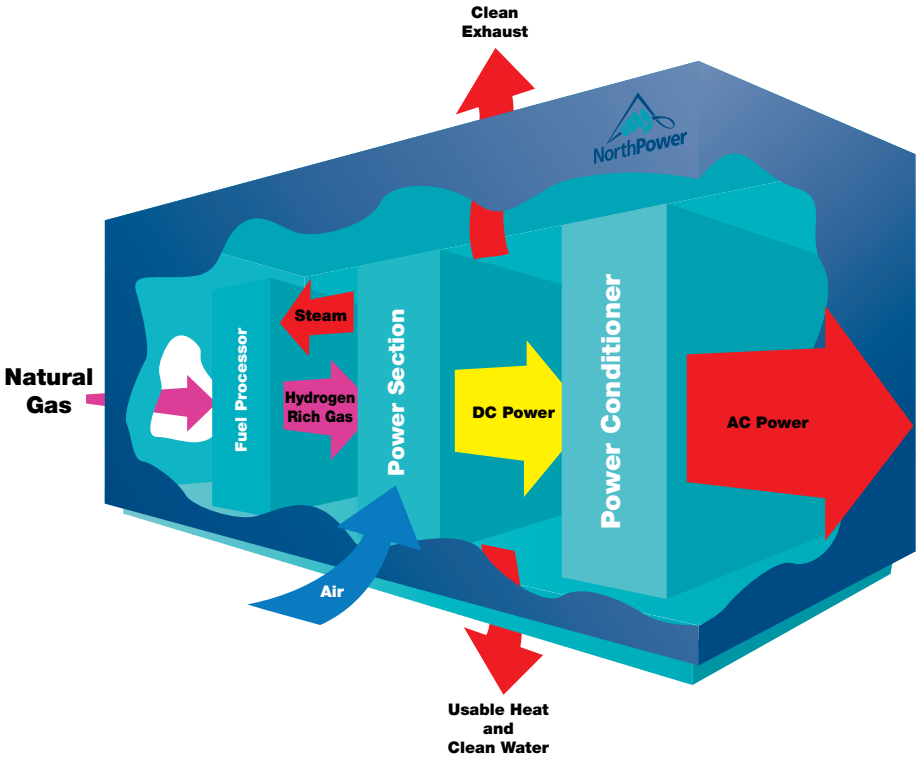
$0_2 + 4H^+ + 4_e^- \rightarrow 2H_20 + heat$

The cathode releases water and heat.

The practical fuel cell

It is not practical or economical to use pure hydrogen and oxygen in fuel cells. Practical fuel cells derive their hydrogen rich gases such as natural gas (methane CH4) The oxygen is derived from air. The only variation to the chemical reaction is that natural gas is processed before use in the fuel cell.

$CH_4 + 2H_2O(steam) \rightarrow 4H_2 + CO_2$



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NorthPower is a leading Australian Energy provider committed to ecologically sustainable development. As well as receiving international certification of our Environmental Management System, pinnacles of our success have included being named as Best Electricity Operator in an international benchmarking study, an increased share of the national energy market, several National Safety Council of Australia Safety Awards of Excellence and national recognition at the 1999 Australian Quality Awards for Business Excellence.

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For further information, contact NorthPower at PO Box 786, Port Macquarie, 2444. Telephone +61 2 6582 8656, Facsimile +61 2 6582 8662, internet www.northpower.com.au.

Fuel cell about to take charge

IAN GRAYSON
❑ Energy

THE southern hemisphere's first commercial fuel cell will begin generating power at the Australian Technology Park within two months.

The cell, which can deliver up to 200kW of power and the equivalent of 250kW of hot water, will supply a biomedical centre and a hotel, which are under construction on the site.

Running on natural gas, the cell provides a fuel-to-energy conversion efficiency rating of 80 per cent, compared with only 30 per cent for conventional power generation facilities.

Such high efficiency means reduced running costs and emissions.

And the cell's manufacturer claims output gasses are cleaner than the air in some major cities.

Although it would cost $1 million to purchase and install, the new fuel cell could provide power more cost-effectively than solar generators, Australian Technology Park energy adviser Brian Jay says.

When initial investment and output were considered, the cell could deliver power at a cost of about $2000 per kW compared with about $15,000 per kW for solar systems.

"I'm certainly not knocking solar generation," Jay says.

"It obviously has its application, but we should also be looking at the whole range of generation technologies.

"This is what we are trying to do at the ATP.

"We are going to be using fossil fuels for the next 100 years at least, but let's use them in the most efficient way.

"That is what fuel cells offer."

He likened the projected growth of fuel cell use to computer systems.

When first developed they were expensive and centralised, he says.

However, a process of development leading to the PC eventually provided processing power to everyone.

"Fuel cells will follow the same path," he says.

"They will eventually provide a cost-effective, distributed form of generation for anyone who needs it."

The concept of fuel cells has existed for more than 150 years.

Experiments in 1839 by scientist Sir William Grove concerning the electrolysis of water showed that, if the process could be reversed, power could be generated.

The cells operate in a similar way to a car battery but run continuously as long as a supply of fuel and oxygen is provided.

Hydrogen ions drawn from a hydrogen-rich fuel are combined with oxygen atoms.

This is used to create chemical reactions at one of the cell's two electrodes which, in turn, creates a small electric current.

The voltage produced by each pair of electrodes, or cell, is chemically limited to a little more than one volt.

To obtain useful power outputs, cells have to be stacked in large quantities.

It took considerable time to expand on the initial idea and produce a working example, but eventually the technology was adopted by NASA to provide power for its first manned space missions in the 1960s.

Since then, research has continued to the point where cells are now being used in some commercial applications.

Jay says automotive companies are particularly interested in the technology as a potential replacement for fuel-driven engines.

Generating power from gas

By Kellie Morle

■ Alternatives to coal fired power are now becoming common and are attracting a great deal of commercial interest.

Leading the charge in upping the profile of alternative technologies is the Australian Technology Park (ATP).

ATP energy adviser Brian Jay said the Park has the only natural gas powered fuel cell in the Southern Hemisphere, one of only 170 around the world.

The project has attracted financial support from commercial sponsors including AGL, Integral Energy, North Power, even the United States Government.

"For a long time people didn't know anything about it," he said.

Jay said he has had interest from gas generators in Queensland and Western Australia.

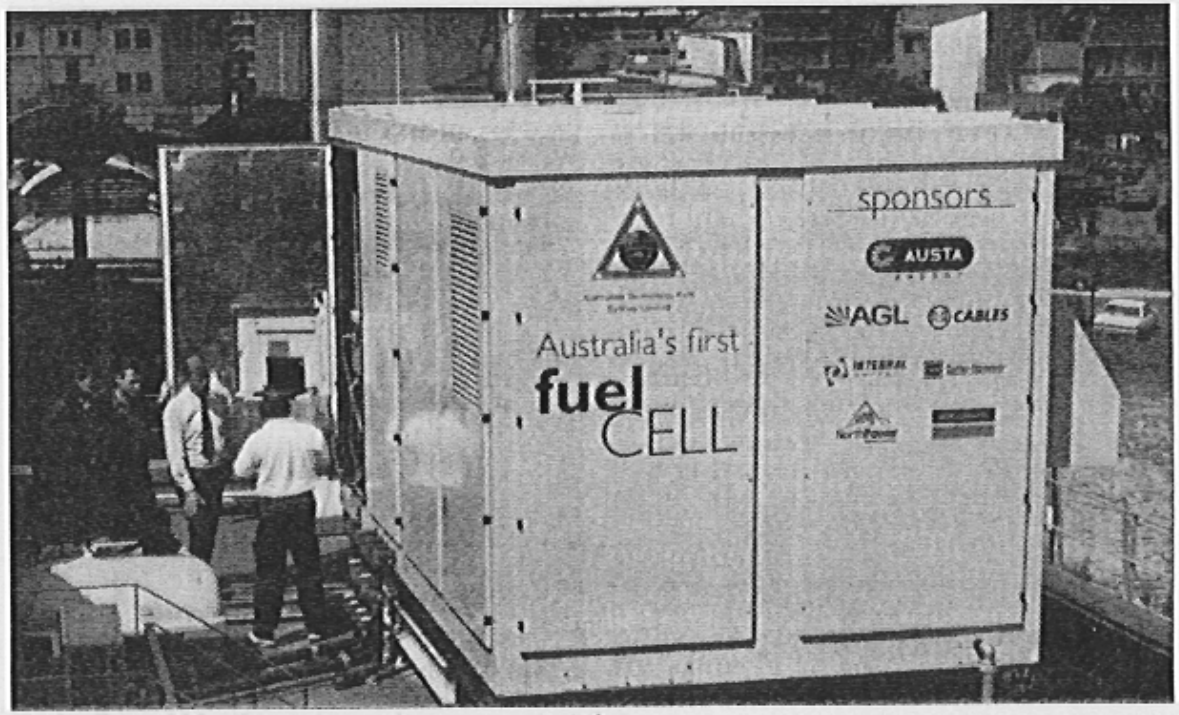
"They are proposing to come down and discuss this with a view to replicating it and producing electricity in a way which reduces greenhouse gas emissions."

Jay said fuel cells are cost effective.

"It does the right thing by the environment. It is 80 percent efficient compared with fossil fuels which come in at 30 percent by the time it reaches the customer."

Fuel cells do not give off sulphur dioxide or nitrous oxide and generate reduced carbon dioxide emissions. The idea for the fuel cell was first mooted in 1839 and came into its own in the American Space Program.

"We recognise that fuel cells have a future and we really have to be up there at the leading edge. Fuel cells have the potential of becoming the power source in every home. By the year 2005 and certainly by the year 2010 we will have a lot of vehicles running on fuel cells. There is talk about powering lap tops and video cameras."



Fuel cells could be the next wave in energy generation

Institute for Sustainable Futures sustainable energy program manager Geoff Milne said the use of gas instead of coal to generate electricity is limited and represents about five percent of all generation.

He said greenhouse gas emissions from electricity produced from natural gas are much lower than coal fired electricity.

"But there is a bit of a problem here with the opening up of the market [deregulation]," he said.

"Victorian electricity retailers can sell into the New South Wales (NSW) market. Quite a lot that is brought here from Victoria is generated from brown coal."

In Australia, 26 percent of electricity generated comes from brown coal and 59 percent from black. Previously NSW was powered predominantly by the the less harmful of the two, black coal.

"The coal from Victoria is one of the reasons that carbon dioxide emissions have gone up in NSW."

He said gas can be a commercially viable alternative.

"Fuel cells are fairly innovative technology"

"[Investing in] a lot more renewables and energy efficient alternatives [is] usually much cheaper than building extra power stations. For a new plant gas would be quite competitive but it is very difficult to compete with existing plants. They are much quicker to build but may be more expensive - but there is flexibility about where they can be located.

"The industry doesn't want to think longer term. The system has a huge amount of inertia and doesn't look at the alternatives available. For many years it has just been geared to supplying lots of electricity."

Supply of coal is almost infinite whereas there is a limit on gas.

Integral Energy environmental energy manager Tony Patterson would not disclose the sponsorship sum for ATP's fuel cell, but said it is a "reasonable sum" of money.

"Without a financial commitment the project would not have eventuated," he said.

"Fuel cells are fairly innovative technology and it gives you an opportunity to look another method of generating electricity. It also has heat as a by-product which allows for cogeneration, a process which increases the efficiency of electricity generation by using by-products to produce more energy.

Another of Integral's projects at Smithfield uses cogeneration.

"The natural gas is fed into turbines to create electricity and the heat from that is exceedingly hot," Patterson said.

"We feed that into a boiler and then the steam is fed into another turbine to produce electricity."

The heat from that process is then on-sold to a waste contractor to dry recycled waste.

Greenhouse Update

Australia's First Fuel Cell CHP Installation

The fuel cell at the Australian Technology Park

Fuel cells operate by the direct conversion of the chemical energy in a fuel to electrical energy without an intermediate combustion stage. They offer the potential to achieve both high electrical generation efficiency and a high thermal efficiency in a combined heat and power (CHP) application with only minimal emissions of associated pollutants. This article provides a description of the first fuel cell installation in the southern hemisphere at the Australian Technology Park (ATP) in Sydney.

Introduction

Fuel cells represent the principal next generation source of mass energy production due to their combined thermal and electrical efficiency of over 80 percent, flexibility of application (automobile to utility size power generation), suitability for the burgeoning area of distributed generation, captive power generation for the chemical process industry, and exceptional environmental responsibility in the use of fossil fuels.

Fuel cells are electrochemical devices that convert the chemical energy of reaction directly into electrical energy. They have been known in concept for more than 150 years and are poised to make significant contributions to power generation.

Sir William Grove is widely attributed to be the father of the fuel cell. His insights were gained from experiments in 1839 into the electrolysis of water. He reasoned that it should be possible to reverse the process and generate electricity by reacting hydrogen with oxygen.

It was the American space exploration missions that saw a major focus into fuel cell technology development. Yet bringing the technology of space to earth has also proven to be a difficult proposition. It has taken over 30 years and more than two billion dollars of research to date and now we are just approaching the commercialisation of fuel cell technology.

A variety of fuel cells are in the various stages of development. These are usually classified by the type of electrolyte used in the cells. They include the proton exchange membrane fuel cell (or PEM), the alkaline fuel cell (or AFC), the phosphoric acid fuel cell (or PAFC), the molten carbonate fuel cell (or MCFC) and the solid oxide fuel cell (or SOFC).

Of all of the fuel cells being developed, apart from the PAFC fuel cell only small experimental research based cells have been developed. The PAFC from the ONSI Corporation in America is commercial and is the one purchased by the ATP.

The Fuel Cell Concept

Fuel cells have often been described as continuously operating batteries or an electro chemical engine. Like batteries, they are a solid state device that delivers power without combustion or the used of rotating machinery.

Fuel cells generate electricity by combining hydrogen ions, drawn from a "hydrogen" containing fuel with oxygen atoms from the atmosphere. All batteries provide the fuel and oxidiser internally, which is why they must periodically be re-energised. Fuel cells however,

continued over page...

Australia's first fuel cell will soon be supplying clean, economical heat and electricity to tenants in the Australian Technology Park (ATP) in the inner Sydney suburb of Redfern.

Australian Technology Park (above & right), Cogeneration Unit (above right), Brian Jay

A fuel cell is a catalytic device that uses no moving parts to chemically convert gas to electricity. The unit being installed is an ONSI Corporation PC25 200kW fuel cell that will be run in cogeneration mode to produce 200kW of electricity and about 200kW of hot water.

AGL, already contracted to supply electricity to the ATP, is a Gold Sponsor of the project and will participate in research and advisory activities associated with the operation of the fuel cell.

ATP grew out of a realisation six years ago that high technology industries together with the University of Sydney, University of New South Wales and University of Technology could gain mutual benefits from working together, sharing technology and inspiring each others innovations.

Dr Tom Forgan was chosen to steer the project to fruition and, despite many obstacles and setbacks, the Australian Technology Park is now operating in refurbished buildings of the historic Eveleigh Railway Yards. Five new buildings will be completed in 1999.

A strict screening process ensures at least 80% of tenants are engaged in research and development while the remainder provide support facilities. Tenants already on site include the Australian Graduate School of Engineering Innovation and companies involved in fields as diverse as health care and fibre optics.

Other intending tenants include a biomedical research centre, an advanced manufacturing centre, telemedicine and ambulance/emergency medical centre and also a Roads and Traffic Authority research and traffic management centre.

ATP is committed to providing its tenants with energy supplies which are both economic and environmentally sound. The roof of one of its buildings already supports 10kW of photovoltaic solar cells.

Brian Jay, Energy Manager, has the task of making the project the most energy efficient development in Australia. He says solar is readily installed on rooftops but as yet is still too expensive at about $15,000 an installed kilowatt and has the drawback of requiring large areas of cell coverage.

ATP Energy Manager (below right)

"A fuel cell can give heat and power for much less. I estimate the installed cost is going to be about $5,000 a kilowatt and we would have had to install an unlimited power supply (UPS) and a standby generator anyway for critical loads. Fuel cells could drop to about $1,000 a kilowatt in the future." Brian said.

The fuel cell will supply critical electrical loads such as used in the medical centre and laboratories that will be installed by Johnson and Johnson in the biomedical building, together with the site management system, computer systems and some of the exhibitions and public areas.

Heat recovery will boost operating efficiency to between 80 and 85%. The heat will be used by the Eco Habitat hotel to be built on site.

The ONSI fuel cell is not experimental but production technology. ONSI now has one hundred and twenty PC25 200kW fuel cells demonstrating reliability and operating efficiency in the Northern Hemisphere. One at the Hyatt Regency in Irvine, California, has surpassed 40,000 hours of cumulative operation since 1992. Studies in Tokyo and Southern California show air coming out of the fuel cells is actually cleaner than air going in.

Sulphur is removed by the fuel processing system and NOx is negligible because of the low inherent temperature of the electro chemical energy conversion in the power plant.

Operation is quiet enough for inner city installation. From 10 meters it is no louder than a domestic air conditioner.

ONSI fuels can run on a variety of gases that have a minimum heating value of 1,500kJ/m3. These gases have a hydrogen molecular content and include natural gas, propane and gas drawn from sewerage and garbage tips.

The PC25 is slightly bigger than a shipping container and easy to hook up to gas, water and electricity.

Brian Jay hopes the ATP fuel cell will be the forerunner of many similar projects in Australia.

"Companies will be able to see our fuel cell in operation and we will be able to provide a great deal of information on how they can apply our experience to installing their own fuel cells for the benefit of Australia!" Brian said.

Groups involved in the Australian Technology Park fuel cell consortium are ATP, AGL, Austa Energy, Integral Energy and Northpower. SEDA provided a loan for some of the costs.

Can AGL help you harness new technologies to reduce your energy costs and environmental impact? Find out by phoning your AGL Customer Manager or AGL on 132 707.

Southern hemisphere's first fuel cell installed

A $1.2 million fuel cell has been installed at the Australian Technology Park in Sydney to demonstrate a new form of power generation.

Photo: Integral Energy

FUEL cells – devices that generate electricity and heat through chemical processes without burning anything – are more than someone's dream: they work, they're available, and they cut greenhouse gas emissions by 70 per cent.

That's the story at the Australian Technology Park (ATP) in Sydney, where the first commercial fuel cell in the southern hemisphere has been installed and is now operational.

The fuel cell, costing around $1.2 million fully installed, produces 400kW of usable energy, half as electricity the other half as heat.

This is about one quarter of the Australian Technology Park's requirements, and is produced at a cost competitive with mains power.

The fuel cell operates on natural gas, but the gas doesn't burn – instead, the chemical energy in the natural gas reacts with the oxygen in the atmosphere to create an electron flow in the presence of a platinum catalyst.

Companies are getting first-hand knowledge about fuel cells without having to outlay the large sum needed to buy one individually.

A consortium of Australian companies who "chipped in" to buy the US-made cell is now getting first-hand knowledge about the function and performance of fuel cells without having to outlay the large sum that would have been needed to buy one individually.

over

HYDROGEN + OXYGEN = ELECTRICITY + WATER

REMEMBER electrolysis? That's the process that uses electricity to split water into hydrogen and oxygen. Fuel cells are the exact opposite – they *combine* hydrogen and oxygen to *produce* electricity and water.

A fuel cell stack is structured like a pile of sandwiches: the bottom slice of bread in each sandwich is the anode, and the top slice the cathode. Both slices allow the transmission of the fuel to the platinum/carbon catalyst - the "margarine". The sandwich "filling" in the ATP cell is phosphoric acid, which behaves similarly to the acid in a battery. Hydrogen fuel (from natural gas) is pumped past the top of the sandwich while oxygen (air) is pumped past the bottom.

The hydrogen enters from the top and in the presence of the platinum catalyst splits into its proton, which has a positive electrical charge, and its electron, which has a negative charge.

The proton and the electron follow a different path to the cathode. The proton passes through the "filling", while the electron follows the closed external electrical circuit, providing power.

When it returns to the cathode, the electron is reunited with the hydrogen and oxygen to form a molecule of water.

Southern hemisphere's first fuel cell installed (cont.)

Participating companies include AUSTA Energy (the principal sponsor), AGL, Integral Energy, Cutler Hammer, Dow Corning, MM Cables and North Power.

The ATP's Energy Adviser, Mr Brian Jay, says the cell, about the size of a shipping container, was purchased from the US manufacturers Onsi, a subsidiary of the International Fuel Cell Corporation, based at Connecticut in the US.

The purchase was assisted with a A$320,000 grant from the US Department of Energy, which has subsidised fuel cell purchases world-wide in recent years.

Mr Jay said similar plants had been installed at more than 150 sites in the US, Europe and Japan, but this was the first in a southern hemisphere nation.

"At the ATP we need not just to be at the leading edge, but at the lead of the leading edge, otherwise we are only catching up.

"Fuel cells are now in their first stage of commercialisation, and it's the right time to evaluate them and see how they fit the Australian scene."

The phosphoric acid fuel cell (PAFC) purchased by the ATP is the only kind of fuel cell so far to reach commercialisation. A variety of others, including a proton exchange membrane cell, the alkaline cell, the molten carbonate cell and the solid oxide cell are still in the experimental stage.

Mr Jay said the fuel cell was a practical solution to reducing greenhouse gases.

"It cuts greenhouse emissions by 70 per cent.

"Admittedly, solar energy cuts those emissions by 100 per cent, but solar still costs at least three times as much as mains power – and you only get solar for five hours a day, if you're lucky, whereas a fuel cell operates for 22 hours a day, taking maintenance into account.

"We need to test the whole arsenal of alternative energy sources."

Contact

Brian Jay, ATP
02 9209 4208 Fax 02 9319 3874

'Venetian blind' to save coal at Qld power station

A SOLAR energy array with nearly-flat mirrors that looks like a "giant Venetian blind" is to be installed at a power station in Queensland to boost the steam supply and save coal.

Shaping up as an excellent strategy to offset the production of greenhouse gases, the technology is the work of the Solar Research Group at the University of Sydney's School of Applied Physics.

The project, to be installed at Stanwell Power Station near Rockhampton in Queensland, was recently granted $2 million as one of five major research projects supported by the Australian Greenhouse Office.

The mirror strips, rotating on their own axis, will track the sun to focus on some 8,700 glass tubes coated with a black "selective surface".

The surface absorbs a maximum of the sun's energy in the visible spectrum while re-emitting a minimum in infra-red.

This allows the tubes to remain cool to the touch even when boiling water inside. To further prevent heat losses, each coated tube is encased inside a clear tube, with a vacuum separating them.

This results in virtually all the sun's heat energy being retained by the water.

It takes only a moderate amount of sun to start the water boiling, and steam produced in the tubes can be fed directly into the turbines of the power station.

The University's evacuated tubular collector system has been under development for 25 years, and early designs have already sold extensively in Japan, Europe and China for domestic hot water.

It has now been developed to a very sophisticated level, with the mirrors and the molecular structure of the selective surface optimised to extract the maximum energy per dollar.

When operational in 2001, the Stanwell project will produce four megawatts of power from an area of two hectares directly beside the power station.

The Head of the Solar Research Group, Dr David Mills, said his team was studying further sites for such installations.

The potential exists for very low greenhouse gas emitting electricity production.

"Costed over 20 years, in these larger sites, we calculate we could produce power at around 7.5 cents per kilowatt hour, which is getting to an acceptable level for daytime power," he said.

If the technology is backed up with thermal storage, fossil fuel or biomass fuel for peaks and overnight power, the potential exists for very low greenhouse gas emitting electricity production.

Dr Mills said there was also potential for distributed systems for hospitals, hotels and shopping centres.

Contact

David Mills 02 9351 3311 (D.Mills@physics.usyd.edu.au)

A commercial fuel cell was installed at the Australian Technology Park in Sydney last year. The article below looks at how the fuel cell works, what it is being used for and why it was chosen. Also included in this feature are articles on the reforms being undertaken in the electricity industry in Tasmania and the ACT, the wind project under way at Denham, WA and two new powerstations in Queensland.

Fuel cell to supply power and hot water to hotel

BY RUTH CARGILL

A COMMERCIAL FUEL CELL was installed at the Australian Technology Park (ATP) in the inner Sydney suburb of Eveleigh last year.

It is a phosphoric acid fuel cell. Fuel cells reverse the principle of a battery. Hydrogen is supplied to the anode where it releases an electron, in the presence of a platinum catalyst, producing hydrogen ions which are then transferred through the electrolyte (phosphoric acid) to the cathode. At the cathode air is introduced. The oxygen in the air is reduced with the hydrogen to produce water and heat as well as supplying DC power.

The unit also contains a steam gas reformer which converts a hydrogen-rich gas into pure hydrogen. The hydrogen-rich gas used in this case is methane in the form of natural gas.

Hydrogen could come from a variety of sources including methane from sewerage systems and landfill gas, from hydrogen streams at a refinery, or propane. As the steam gas reformer converts the hydrogen-rich gas to pure hydrogen, it releases carbon as CO_2. Sulfur is scrubbed from the gas. No hydrogen is released to the atmosphere, as any hydrogen which passes through the cell is reused as the source of energy for the steam gas reformer. Overall, fuel cells eliminate up to 2/3 of the greenhouse gas emissions.

According to Brian Jay, energy manager at the ATP, the overall efficiency of the fuel cell is about 80%. "That's made up of about 40% electrical and about 40% thermal," he said. The thermal output of the cell is in the form of hot water at 65°C. The hot water will be used by the Ecohabitat Hotel which is to be built at the ATP and completed next year.

"The unit could have been purchased with a dual heat exchanger process where half of the water would have come out at 120°C and half at 60°C-65°C. However, the hotel needed all of it at 65°C," Jay said.

The fuel cell is capable of supplying 200kW of electrical power and about 200kW of hot water. Eventually its full time electrical load will be the critical energy needs of Johnson & Johnson, one of the tenants of a biomedical facility to be completed later this year, and the hotel. Until these loads come online the fuel cell is being used to supply a dedicated load within the ATP.

The fuel cell will provide a continuous supply to the critical energy needs which would normally be backed up by a diesel generator or UPS (uninterruptible power supply) system.

According to Jay phosphoric acid fuel cells are the only ones which are commercially available, although other technologies are being developed.

Fuel cells were first thought of by William Grove last century. However, it was the US Space Program which resulted in the process being revisited and further developed. Alkaline fuel cells require pure oxygen and, while they have been widely used in the US Space Program, have not been considered for terrestrial application. Other types of fuel cells include molten carbonate, proton exchange membrane (PEM), and ceramic. Researchers in Victoria are working on a commercial ceramic fuel cell.

The fuel cell at the ATP was purchased from ONSI, an arm of the International Fuel Cell Corporation, based in Connecticut, US. The company has supplied all the fuel cells for the US Space Program.

The phosphoric acid fuel cell at Sydney's Australian Technology Park.

There are about 160 units similar to the one installed at the ATP in operation in the northern hemisphere.

Jay said the ATP had chosen the fuel cell because it is at the leading edge of technology development for power generation and because fuel cells are the best technology for the elimination of greenhouse gases on a dollar-for-dollar basis. "The fuel cell costs about $1.2 million installed, or about $3000/kW. Compare this with $12,000/kW$_{peak}$ installed for solar energy systems, which is the figure the NSW treasurer recently quoted," he said.

MORE INFO? CIRCLE INFOCOUPON 18

Jay said other advantages of the fuel cell over solar are that the fuel cell is expected to produce a daily average of more than 20kWh/kW throughout the year, compared with about 4.5kWh/kW for solar; and that the fuel cell takes up a lot less space than an equivalent energy producing solar array. "I'm not knocking solar, but we need to use the whole armoury of technologies to eliminate or reduce greenhouse gas emissions," he said.

The project to install the fuel cell, which is owned by ATP, has had a number of sponsors. The principal sponsor is AUSTA Energy. AGL is a gold sponsor, Integral Energy a silver sponsor, and Northpower, Dow Corning, Culter-Hammer and MM Cables are sponsors. SEDA provided a loan for some of the funding.

The fuel cell has a projected lifetime of about 20 years. An extensive cell stack overhaul is required after five to seven years. Filter cleaning is required about every three months and an annual shutdown of a couple of days is required for general maintenance. Maintenance is done locally but the manufacturer also conducts, remotely, a daily diagnostic check of the fuel cell performance and gives the owner advice on maintenance when required. ■

Denham: powered by wind

AFTER THE SUCCESSFUL opening of a single wind turbine at Denham on the midwest coast of Western Australia, Western Power has received a federal government grant to add a further two turbines at the same site.

The project to install the first turbine was completed last July and officially opened in October by WA energy minister Colin Barnett. It involved the installation of the turbine and its tower, an automatic control system at the Denham Powerstation, communication equipment between the wind turbine and the powerstation, and a SCADA system for remote system monitoring in Perth. The project was undertaken by Western Power, the main energy provider in WA, at a cost of $950,000.

This single wind turbine at Denham, WA, is to be accompanied by two more later this year.

In December Western Power received a $1 million grant from the Renewable Energy Showcase Program which is administered by the federal government's Australian Greenhouse Office. The grant, along with a further $1.85 million from Western Power, will see a further two identical turbines, an energy storage system and an upgrade of the control system installed in Denham this year.

Denham has a population of about 800 and is not connected to the main WA electricity grid. Until the installation of the first turbine, the town's power needs were supplied by diesel generators. The turbine currently generates 20% of Denham's average system load, and at times reaches instantaneous penetration levels of 65%. Over the first six months of operation this has translated to savings of over 90,000L of fuel, and 250t of CO_2 emissions.

The aim of the project extension is to produce 70% of the town's annual energy requirements from wind. To assist in this aim some energy storage is required so less diesels are required online to provide "spinning reserve" coverage of wind turbine output. It is expected that at times the entire town load will be able to be supplied from wind power with the energy storage providing back-up capacity.

The energy storage system is expected to be provided by advanced lead-acid batteries, although the idea of also including commercially available flywheels is being investigated.

The three turbines combined will save about 575,000L of fuel and 1700t of CO_2 emissions each year.

The single turbine is an Enercon E30 230kW designed and manufactured by the German company Enercon and built by one of its subsidiaries in India. The turbine has three 20m long blades and is positioned atop a 50m tower which can withstand cyclonic winds of up to 230km/h.

The E30 is a variable speed turbine which means the blades speed up and slow down with the wind speed. The connection to the grid is through an inverter which offers considerable control over the power quality.

Powercorp Ltd, specialist in the design and control of remote hybrid power systems from the Northern Territory, has been working with Western Power on both the projects.

The control system for the initial project was designed in Australia by Powercorp. It automatically governs how the generating plant is managed to minimise fuel usage and maximise the use of wind generation. It brings on or takes off diesel generators as required, controls the wind turbine output and takes action following faults. It also initiates any necessary feeder tripping in the event of under-frequency resulting from plant failure, and automatically reestablishes tripped feeders once adequate generation is brought on-line.

While it dispatches the generating plant, the initial control system does not control frequency or voltage. When the two new turbines are installed it will be upgraded to manage the two additional turbines, the energy flow to the storage system as well as provide system frequency and voltage control.

For several years prior to the installation of the first turbine an extensive wind monitoring program was undertaken in Denham by Western Power, to assist in the long-term prediction of the available wind resources. The average wind speed is above 8m/s (28.8km/h) and in the first six months of operation has been within 4% of that predicted. The turbine output for the same period has been about 5% more than anticipated.

One of the aims of the initial project was to: study the operation of the hybrid system and to formulate the diesel dispatch algorithms that maximise the use of available wind generation.

This resulted from the project being a demonstration project for the Australian Cooperative Research Centre in Renewable Energy (ACRE) at Murdoch University in Perth. ■

The
Institution of Engineers,
Australia

URGENT FACSIMILE
Page 2 of 2

TO: The Chief Electrical Engineer (and staff notice boards, please!)

EEEVic comprising: IEAust IEE IEEE IREE TSA

NOTICE OF JOINT TECHNICAL MEETING

Fuel Cell Technology

presented by

Dr Bruce Godfrey

Ceramic Fuel Cells Pty Ltd

Mr Brian Jay FIEAust

Energy Manager, Australian Technology Park, Sydney NSW

on

Monday 16 August 1999

at

6.00 pm for 6.30 pm start

Discovered in 1839, Fuel Cells have recently attracted renewed attention because of their potential for producing more efficient and pollution free electric power and heat in both stationary and vehicle power applications. This session is devoted to informing members, their guests and other interested people of the staggering worldwide effort that is going into this development. There will be two speakers, as well as a display of material. Dr Godfrey will present an overview of the technical principles and applications of the various types of Fuel Cells and describe the development work carried out by his organisation in Melbourne. Mr Jay will describe a Fuel Cell power plant, now operating at the Australian Technology Park with a rated output of 200 kW electrical power plus 200 kW of thermal power. Displays of material from various vehicle manufacturers who are in the course of developing fuel cell powered vehicles, some of which have already been trialled on the road, is also being negotiated.

Venue:	Institution of Engineers, Australia Victoria Division Office 21 Bedford Street, North Melbourne
Cost:	Free
Registrations:	Not required. Visitors welcome.
Further Information:	Fred Clerk 9565 9706 email at clerf@hrl.com.au

Forthcoming Meetings: 20 September - Fuzzy Management

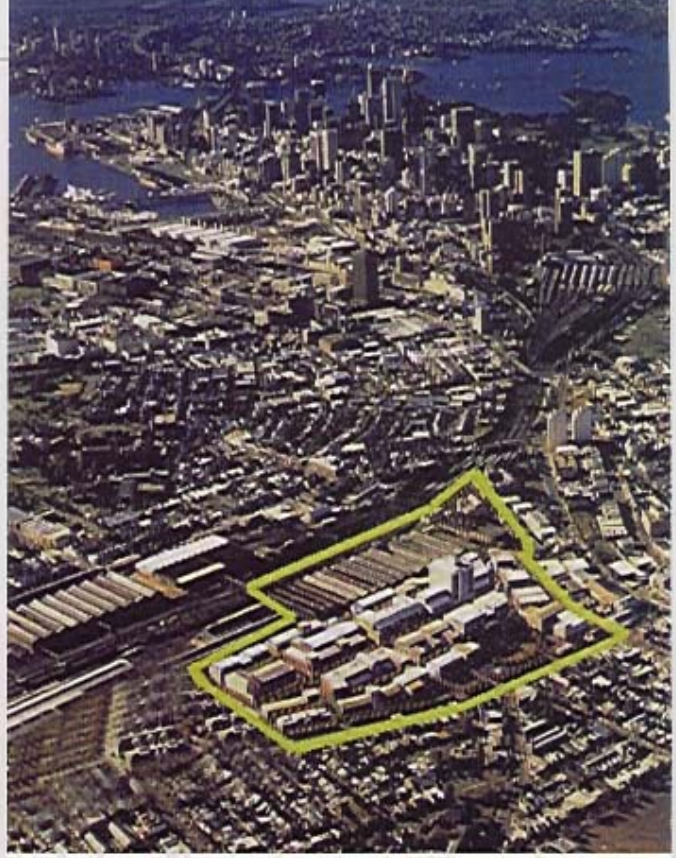
Tuesday 19 October

10.10am **Business Session II —Gas Power Generation/Cogeneration/ Fuel Cells**
Plaza 1 Room

Fuel Cells — The Australian Experience

Dr Brian Jay
Manager
Australian Technology Park Sydney Ltd

Mr Jay, a Fellow and Division Committee Member of the Institution of Engineers of Australia, worked for Energy Australia for almost 35 years and represented that organisation on a number of professional development organisations. He formed a consortium from energy organisations that enabled the ATP to place an order for the first fuel cell to be installed in the Southern Hemisphere and is a Director of a company established to develop a wind turbine in Australia.



An aerial view (right) highlights the proximity of the Australian Technology Park to the Sydney CBD. The ATP links industry with the world-class research facilities of its three sponsoring universities – the University of Sydney, the University of NSW and the University of Technology, Sydney (UTS). Together, these universities receive more than 25 per cent of the total Commonwealth research grant.

which Government has awarded it. But each State will then be able to tailor the program to meet its own circumstances, for instance, it might want to focus on particular industries or strengths."

Australian Technology Park

New developments worth $260 million, including a 400-bed "high-tech hotel" will be completed at the Australian Technology Park in Sydney in time for the Olympics.

ATP Chief Executive Officer Dr Tom Forgan expects most VIP visitors to the Olympics will ßvisit the ATP, situated directly on the route between Sydney airport and the CBD.

An example of the kinds of installations that will attract visitors, he said, was the "nerve centre" of the NSW Roads and Traffic Authority (RTA), to be situated in a new $10 million building.

"This will be a state-of-the-art facility that will automatically attract traffic controllers from around the world," Dr Forgan said.

"Being part of a technology park means they are committed by their lease to trialling new technologies, so they become a market pull to our own transport systems researchers.

"The NSW Ambulance Service will also have a satellite tracking facility here, and will be trialling telemedicine, which will become a market pull for our biomedical companies."

The 400-bed high-tech hotel, due for completion by June 1999, will have a hydroponics garden on the roof, an advanced fuel cell to convert natural gas into electricity and hot water, and a "smart card" which will not only get visitors into and out of the hotel and car park, but will give access to a range of spaces around the park and have other functions including cash.

The 400-bed high-tech hotel, due for completion by June 1999, will have an advanced fuel cell to convert natural gas into electricity

Although the hotel is intended to provide serviced apartments for visiting participants in research programs, most of the visitors are expected to be hoteliers in the first year.

The park will also have an vanced fibre optic Local Area Network (LAN), installed as a demonstration with the Australian Photonics CRC.

The CRC has taken a world lead in fibre optics with its capability to transmit numerous channels on a single fibre using multiple "colours" or wavelengths of light.

"At present we are just at the beginning of the photonics age," CRC Chief Executive Dr Mark Sceats said. "Conventional optical fibres have one source and one detector, which is a pretty primitive arrangement, comparable with the copper wire at the beginning of the electronics age.

"What we've been able to do is to send different wavelengths which can be directly routed from one node on a network to a different node."

The high-performance LAN to be installed at ATP will be quicker than conventional time division multiplexing LANS, in which data is packaged and has to wait for a "break in the traffic" before being sent off.

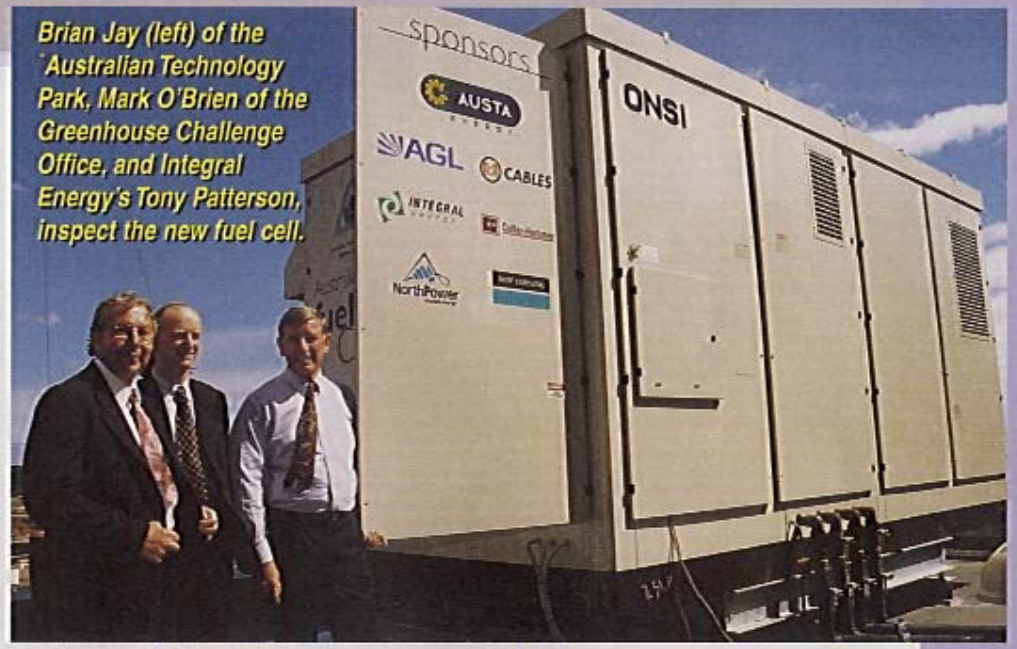
It will offer huge bandwidth, making it possible to demonstrate high data transfer tasks like virtual shopping.

over

YET ANOTHER 'FIRST'

We sponsor top fuel cell technology

Greenhouse Challenge



Brian Jay (left) of the Australian Technology Park, Mark O'Brien of the Greenhouse Challenge Office, and Integral Energy's Tony Patterson, inspect the new fuel cell.

Australia's first fuel cell power plant is up and running, and Integral Energy is at the cutting edge of the technology.

We're one of four sponsors of the fuel cell, installed at the Australian Technology Park (ATP) on the site of the former Eveleigh locomotive workshops near Redfern in Sydney.

The 200kW fuel cell converts natural gas through chemical action to AC power and provides useable heat and clean water as by-products. Best of all, the cell is described as the most environmentally friendly fossil-fuelled energy generator - and it's very quiet.

Apart from contributing to our knowledge of alternative energy sources, there will be other benefits from involvement in the fuel cell project according to Environmental Energy Manager Tony Patterson.

"The electricity and heat generated by the cell will be sold to Technology Park tenants so the sponsors will receive a small financial return," said Tony, adding, "More important, it will provide us with a further source of greenhouse gas reductions, adding to our already high record in this area.

Detailed financial, commercial and technical data will also become available, giving Integral Energy the opportunity to make a full business assessment of the fuel cell and its capabilities," he said.

Tony said a further advantage of the fuel cell is its immunity from storms and lightning and other network reliability issues.

Technology Park tenants likely to use the premium electrical output from the fuel cell include a proposed biomedical building, computer systems, site management systems, ambulance/emergency medical centre, and traffic management. Heat energy output will go to a hotel, now under construction on the site.

Fuel cell technology was first raised as a possibility in 1839, but it took almost 100 years for the first practical demonstration.

In the late 1950s and early 1960s, NASA sought a compact way to generate electricity on board its planned space missions, eventually using them aboard Apollo and Space Shuttle launches.

The fuel cell at ATP, also the first in the southern hemisphere, was manufactured by the same organisation that produces the cells for NASA.

Think ahead - put solar on top

connected to mains power through a grid interactive inverter. This inverter converts the dc electricity from the solar modules to AC electricity, which then joins your existing mains power at the meter box.

Platypus Power Hydro systems which simply harness the energy of

stretching your brain, it will also give you a chance to 'keep energy on your mind'. The first five readers to have all the correct answers will each receive a special renewable energy prize.

Q1. If we determined that a customer's daily load was 3600

solar radiation that produces this effect? Hint: Photoelectric effect is right on.

Q4. The device (box) that changes the battery power from DC (direct current) to AC (alternating current) is called a what? Hint: See Q6.

EEA

Electricity Engineers' Association of NZ (Inc.)

Annual Conference & Trade Exhibition

Innovation For Success

15-16 June 2001, Sheraton Hotel, Auckland

The major forum for the dissemination of engineering knowledge and product information within the New Zealand Electricity Supply Industry

Major Sponsor

energex

Conference Programme 2001

FRIDAY 15 JUNE

08.30	**Trade Exhibition Open - Rangitoto Ballroom and Prefunction Areas**	
	Tamaki/Akarana Room	**Westhaven Room**
10.00 - 10.30	**Opening Address** - Jeanette Fitzsimons MP, *Co-Leader, Green Party*	
10.30 - 11.00	**"Regulatory Change: Concentrating on the Electrical Industry"** - John Belgrave, *Chairman, Commerce Commission*	
11.00 - 11.30	**"Fostering Innovation"** - John Walker, *EA Technology Ltd*	
11.30 - 12.00	**"Risk Management or Failure Avoidance"** - Robin Johansen, *Analytix*	
12.00 - 13.30	Lunch	
13.30 - 14.00	**"Fuel Cells-30 Years of Operational Experience"** -Dr Brian Jay, *Australian Technology Centre* -Bill Woods, *Team Power*	**"Dynamic Rating of Power Transformers - Managing a Large Asset"** - Michael Witte, *Dynamic Ratings Pty Ltd*
14.30 - 15.00	**"Fuel Cells-A Solution for Tomorrow"** - David Worsnop, *Alstom*	**"A Transformer Thermal Model"** - Dave Faville, *Mighty River Power*
15.00 - 15.30	**"Fuel Cells- "Is the Sky Falling on NZ Network Companies?"** - Andrew Renton, *Meritec Ltd*	**"Applications of On-line PD Monitoring Techniques"** - Yafei Zhou, *Industrial Research Ltd*
15.30 - 16.00	Afternoon Tea	
16.00 - 16.30	**"Mandated Renewable Energy Targets -A Strategy for New Renewables"** - Peter Browne/Alistair Wilson/ Ian Shearer, *Wind Energy Association*	**"Predicting Remaining Life of Bare Overhead ACSR Conductors"** - VM Linton/SJ Swann/ KA Licht, *Materials Performance Technologies Ltd*
16.30 - 17.00	**"Economic Aspects of Siting Embedded Generation in Sub-transmission Networks"** - Peter Armstrong, *Meritec Ltd*	**"Probabilistic Transmission Line Rating"** - Bruce Smith, *Transpower NZ Ltd*
17.00 - 17.30	**"Hamilton's Waste Water Treatment Plant Cogeneration Facility"** - David Lynch-Watson, *Beca Carter*; Martin Lynch, *Hamilton City Council*; Allan Campbell/Rachael Clapham, *Beca Steven*	**"Uprating of 110 and 132kV Double Circuit, Steel Tower Transmission Lines"** - Tony Gillespie, *Powerlink Queensland*
17.30 - 18.00	**"Loss of Mains Detection Using Enhaced Detection Criteria"** - Jurgen Schmitz, *AVK/SEG*	**"Polymer Compounds used in HV Insulators"** - John Rumble, *Hubbell Power Systems*
18.00 - 20.00	Social Gathering : Trade Exhibition Areas	

SATURDAY 16 JUNE

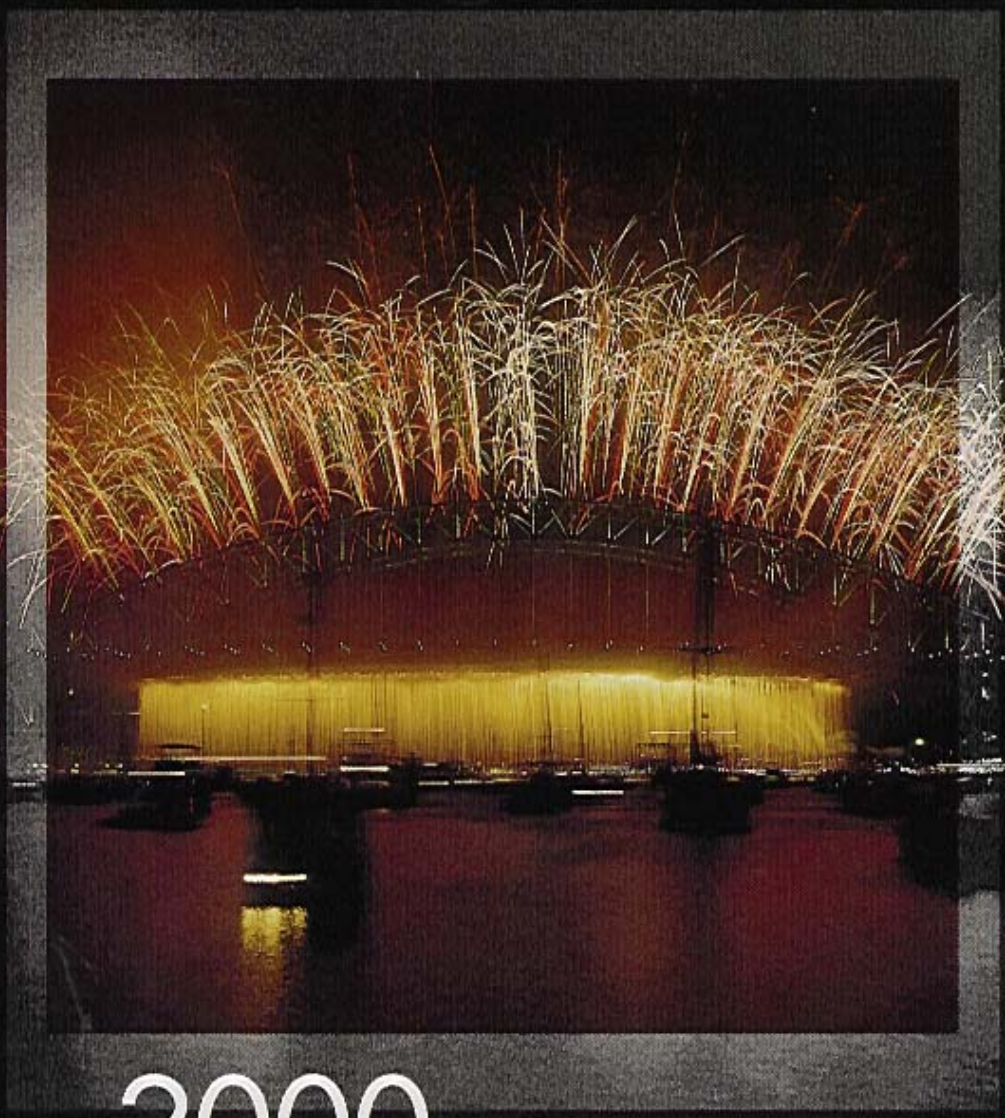
07.45 - 09.00	**EEA Annual General Meeting-Members Breakfast (Westhaven Room)**	
09.00 - 09.30 09.30 - 10.00	**"Future Proofing the Industry - Finding the New Engineer"** - Assoc. Prof. R Duke, *University of Canterbury*; Geoff Hunt, *Alstom*; Kevin Mackay, *Transpower NZ Ltd*, Richard Aitken, *Beca Group*	
10.00 - 10.30	Morning Tea	
10.30 - 11.00	**"2001 Contracting Philosophies and Practices Implications on Safety and Quality"** Fiona Fifield/Ross Parker, *Tri-Sheras*	**"Installation and Maintenance Experience with Optical Fibre Ground Wires"** - Mike Taylor, *Transpower NZ Ltd*
11.00 - 11.30	**"Successful Disaster Recovery"** - WD (Mac) McIntosh, *Odyssey Energy Ltd*	**"When a House is Actually a Substation"** - Rhys McDougall, *Sinclair Knight Merz*
11.30 - 12.00	**"Implications of Recent Inquiries for the Electricity Industry"** - Harvey O'Sullivan, *Tri-Sheras*	**"Distribution Cable Installation and the Impact of Trenchless Technology"** - Brian Enright, *Connetics Ltd*
12.00 - 12.30	**"Innovations in Fall Protection and Work Positioning in the Electrical and Communications Industry"** - Ian Travers, *Dalloz Safety*	**"Christchurch CBD Reinforcement Project"** - Dinesh Mehta, *Orion NZ Ltd*; Naveed U Rahman, *Olex Cables NZ Ltd*
12.30 - 14.00	Lunch	
14.00 - 14.30	**"Basis for a Forward Looking Valuation Methodology"** - George Horvath, *Meritec Ltd*	**"Earthing Systems- Testing for Safety"** - Tony Mitton, *Mitton Consulting Ltd*
14.30 - 15.00	**"The Network Monopoly- Fact or Fiction"** - Roger Loveless, *Odyssey Energy Ltd*	**"Network Automation-UK Knowledge Applied in New Zealand"** - Henry Smith, *Hawkes Bay Network Ltd*
15.00 - 15.30	**"Reliability Incentives in a Regulated Environment"** - Geoff Brown, *PB Associates*	**"Delivering Enhanced Access to Network Services"** Maarten van der Zeyden, *Utility AP*; Stuart Smith, *UnitedNetworks Ltd*
15.30 - 15.45	Afternoon Tea	
15.45 - 16.15	**"Use of Network Agreements-An Innovative Framework and New Ethos for a Dynamic Industry"** - Matthew Todd, *UnitedNetworks Ltd*	**"Utilities Asset Management Aided by Innovative Use of Lightning Detection Network Technology"** - Jitesh Raniga, *Transpower NZ Ltd*; Peter Fisher, *Meteorological Service of NZ Ltd*
16.15 - 16.45	**"Operation of 3-Phase Induction Motors on a 1-Phase Mains Supply"** - Prof John Boys/ Dr Udaya Madawala, *University of Auckland*	**"Global Monitoring of Electricity Supply"** - Deion Campbell, *CHK Wireless Technologies*
16.45 - 17.15	**"Distributed SMES - A New Technology Supporting Active Grid Management"** - Ron Davey, *Power Consultants Ltd*	**"Real Time GIS"** - Peter Law, *Intergraph Corporation (NZ) Ltd*
17.15 - 17.30	Closing Remarks	
19.30 - 20.00	Pre Dinner Drinks (Sky City Casino)	
20.00 - 00.00	Conference Dinner and Awards Ceremony (Sky City Casino)	

EEA

Electricity Engineers' Association of NZ (Inc.)

** This programme is correct at the time of printing. The EEA reserves the right to amend the advertised programme where necessary.*

Program



After 2000
The Future of Mining

The Impact of New Technology and Changing Demands on The Mining Industry

Australian Technology Park
10 - 12 April 2000
Sydney, Australia

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CMTE

AUSTRALIAN TECHNOLOGY PARK (ATP)

The University of New South Wales, The University of Sydney and the University of Technology Sydney as members and stakeholders jointly own the Australian Technology Park (ATP).

The ATP, located on a formerly derelict, heavy industrial, 13.8 hectare site (once the Eveleigh Locomotive Workshops), is currently being transformed into an advanced technology park. The ATP is now being recognised as a strategically located precinct that is already generating substantial socio-economic benefits to the State and local communities.

The redevelopment of the ATP has contributed to establishing a current (30 June 1999) site valuation totaling $230 million, up from a negative base just four years ago.

The mission of the ATP is captured in its motto, "our business is growing new business" and its aim is to be the premier science and technology park in the Asia Pacific Region. Already the ATP has not only become Australia's leading technology park but is also currently recognised by government as the preferred model for Queensland and Victoria. Through the integrated research strengths of its founding universities, representing more than 25% of national research grant awards, the ATP acts as a hub to link their world-class research facilities to industry and to the wider community.

To facilitate further growth of the ATP by gaining access to new capital funding arrangements, the NSW Government will be shortly assuming control and ownership of the ATP's property assets and commercial operations. A new university company is being formed with likely participation from the Australian National University to direct the technology and business development aspect of the ATP's mission.

Australian Photonics Cooperative Research Centre

Photonics is an emerging area of technology with a diverse range of applications in communications and sensing, with particular relevance to the minerals industry. Australia is a world leader in this field.

The Australian Photonics Cooperative Research Centre (Australian Photonics CRC) has facilities and its headquarters at the ATP, the other principal divisions being located at The Australian National University and at The University of Melbourne. The mission of the Australian Photonics CRC is threefold - research, education and training, and commercialisation. Commercialisation has been effected by collaboration with companies wishing to use photonic technologies, and by starting companies based on the CRC's research. An important strength of the Sydney Division of the CRC is the optical fibre fabrication facility within Sydney University's Optical Fibre Technology Centre.

There will be a limited number of places available for short tours of the optical fibre fabrication facility led by Dr Ian Bassett. The Head of the CRC, Professor Mark Sceats will also provide an introductory briefing.

The Australian Centre for Advanced Communications and Computing – (AC)³

High performance and communications (HPCC) delivers high speed processing of vast data sets and is the preferred platform for visualisation, virtual reality and simulation. Already widely used in the petroleum industry, HPCC technologies are increasingly playing a role in the minerals industry for a wide range of applications.

Financially backed by the NSW Government and a consortium of NSW universities, (AC)3 is currently being established at the ATP with the world's most powerful computer systems from IBM, NEC/HP, SUN Microsystems Australia and SGI. This $24 million facility will consist of a central system located at the ATP with regional nodes in Newcastle, Wollongong, Penrith, Bathurst, Gosford, and Armidale and high bandwidth links (using photonics technologies) to other facilities interstate and overseas in Singapore and San Diego.

A tour of one of the existing and subsidiary HPCC facilities (VISLAB) will provide an insight into how HPCC can be used for decision making. Dr Peter Jones the (AC)3 founding project leader will also provide a briefing about the whole project.

The ATP's Fuel Cell - Australia's First!

Commercial fuel cells can be transported to remote field locations where natural gas can be converted into electricity.

The Australian Technology Park (ATP) has the only commercial fuel cell in the Southern Hemisphere. Fuel cells are one of the emerging technologies that are responding to the challenge to reduce and control the level of greenhouse gas emissions.

The ATP Fuel Cell supplies electricity to the critical electrical needs of Johnson & Johnson in the Bio-Medical Centre and will be used to supply the planned (AC)3 facility at the ATP. The fuel cell project was backed by a consortium formed by the ATP and includes the US Government, AUSTA Energy, AGL, Integral Energy and NorthPower, Pirelli Cables, and Cutler Hammer as sponsors. The NSW Sustainable Energy Development Authority also provided some loan funding.

Fuel cells generate heat and electricity from natural gas or other hydrogen rich gases such as 'digester gas' from sewerage or land fill gas. Fuel cells can be viewed as a continuously fuelled battery, except that they reverse the normal processes that occur. Within the fuel cell, heat and electricity are chemically produced from the fuel with an overall efficiency greater than 80%. The high efficiency means the operating costs are low and that there are environmental benefits, including a reduction in greenhouse gases in NSW. Currently the fuel cell is reducing greenhouse and other emissions in NSW at the rate of 100 tonnes per month.

A tour of the ATP installation (led by project leader and engineer, Brian Jay) will show the fuel cell manufactured by the ONSI Corporation of Connecticut in the USA as well as the associated control and management of the facility.

ATP Business Incubator Program

Incubator facilities are becoming increasingly used to assist innovators (including post grads from universities) to commercialise research outcomes. It is conceivable that a 'minerals industry' incubator program may emerge as the Australian minerals industry examines new ways of 'fast tracking' technological innovation.

Of the some 90 organisations working in the ATP, some 40 constitute the ATP's 'high tech' business incubator program. Most of the incubators are developing technologies in the areas of e-commerce, Internet, multi-media and software development with others engaged in environmental technologies and biotechnology.

Business Incubator General Manager, Mr Stan Jeffery, will conduct a tour of the incubator facilities and will provide a briefing of how the incubator program is funded and operates.

ATP TOURS – Please book at registration desk

Events Department
The AusIMM, PO Box 660, Carlton South,
Victoria, Australia 3053
Telephone: +61 3 9662 3166
Facsimile: +61 3 9662 3662
Email: conference@ausimm.com.au

Demonstrated Reliability During Extreme Conditions

Sydney's Hail Storm 16th April 1999

On the evening of the 16th April 1999 and whilst the fuel cell was delivering electricity to the ATP system Sydney endured one of the most severe hail storms in it's history. The ATP situated as it is between the Sydney Airport and the Sydney Central business District and therefore encountered the worst of the storm. The ATP roof was damaged and required replacing as well as more than 100 window panes were smashed and therefore replaced. Vehicles parked at the ATP were written off due to hail damage.

The fuel cell cooling module showed some minor denting, but continued to operate throughout the storm as did the fuel cell. The following cuttings from the newspapers following the storm clearly demonstrate the severity of the storm. The ability of the fuel cell to not only endure the storm but to continue to deliver set power throughout is a testimony to the reliability of the system.

THE
Daily Telegraph

SYDNEY, Friday, April 16, 1999 | Weather: Fine, 22 degrees | www.news.com.au | 80 cents* M

Ice storm — The brutal reality

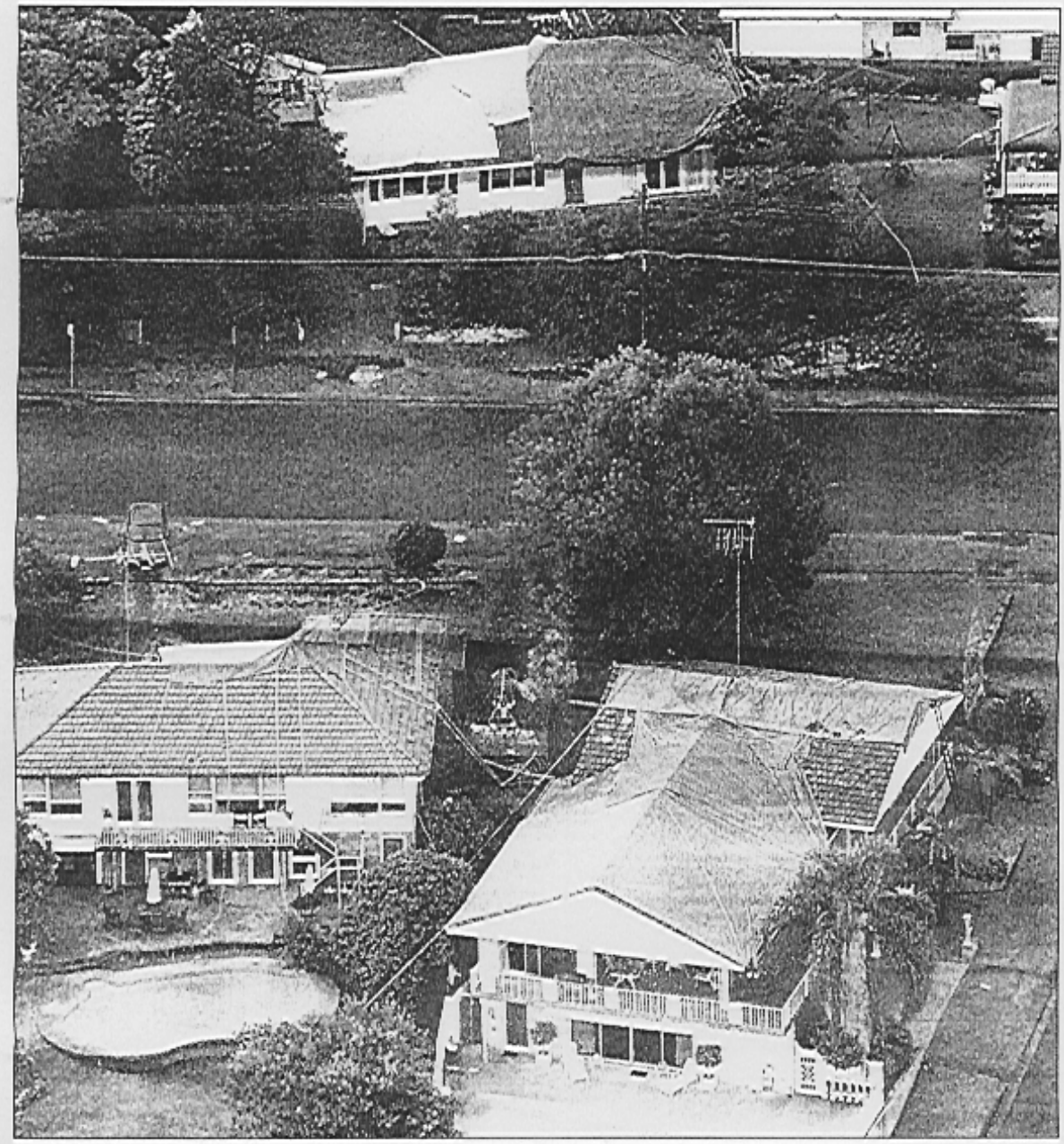
SHATTERED

Aftermath . . . Rosebery resident Greg Moore surveys the damage to his roof yesterday as daylight revealed the devastation from Wednesday's storm. Picture: DAVID WHITE

- **20,000 homes damaged**
- **60,000 cars ruined by hail**
- **Record $350m repair bill**

Reports and pictures: Pages 4,5,6,7,11

Our 2500sq km



Tarpaulins adorn three houses in the storm-struck suburb of Caringbah yesterday

Picture: Troy Bardoch

$350m bill as Sydney mops up

By KIM SWEETMAN

AN AREA of 2500sq km, stretching from the south coast to Sydney's northern beaches, was declared a natural disaster zone yesterday in the wake of Wednesday night's hailstorm.

Daylight yesterday revealed the true extent of the storm, which insurers said had left a record repair bill of $350 million.

It was a night for records. A 9cm diameter hailstone which smashed through a roof in Surry Hills was the largest recorded in NSW.

More than 60,000 cars and 20,000 homes, from suburban bungalows to city apartments, were damaged by hail, wind and rain.

Emergency services workers said they were amazed the storm claimed only one life — that of an angler apparently struck by lightning in his aluminium dinghy in Dolans Bay in the city's south.

Shell-shocked residents directed their anger at the weather bureau for failing to warn about the storm.

Bureau of Meteorology NSW director Patrick Sullivan defended the bureau, saying: "If we over-warn we cry wolf, and people then will not have much faith in our forecasting."

He said the lack of a warning was "unfortunate" but added meteorology was an inexact science.

"The forecaster's confidence was such that it would move offshore that a warning was not sufficient," he said.

Mr Sullivan said the stormfront developed south of Wollongong (at mid afternoon) but swung offshore at Port Kembla, travelling parallel to the coast and dumping rain and light hail in the Wollongong area.

"The judgment of the forecast team was that the storm would be steered more and more away from the coast as it moved north," he said.

"However, the atmosphere is fickle and the storm did not move as forecast.

"Rather, it took a course across some of the most densely populated areas of Sydney from Sutherland to Pittwater."

By 7.30pm storm had pushed north across Sydney, its raw power carving a random pattern of destruction which saw entire streets uprooted and neighbouring ones left relatively untouched.

Almost every house in Cottenham St, Kensington, was damaged

Protests halted $2m storm warning system

By SIMON BENSON
Environment Reporter

A $2 MILLION radar system specifically designed to warn of severe storms was due to be installed more than a year ago in southern Sydney but had been delayed because local residents complained about it, *The Daily Telegraph* learned yesterday.

Designed to issue alerts to forecasters when storm cells develop into threatening situations, meteorologists concede that the Doppler radar would have issued automatic warnings about the storm as it suddenly intensified.

Ironically, the residents who complained about its introduction — mostly around the southern suburbs of Kurnell — were among the first to be hit by Wednesday's hailstorm.

The radar warning system was ordered following a Federal Government inquiry less than two years ago which warned of a major "public catastrophe" if proper funding and resources were not made available to the agency.

It was to be the centrepiece for the future training of all forecasters across the country and has been used extensively in the US for years as an early warning system for tornadoes. The Doppler system was installed at Kurnell four weeks ago — and was right in the path of Wednesday's storm.

But meteorologists at the weather bureau have not yet been fully trained in its use.

The NSW manager of the Bureau of Meteorology Bruce Buckley last night confirmed that the system was due to be installed a year ago but community concerns about radiation delayed the project.

"We had to go through an involved process. There were concerns expressed by residents ranging from radiation of water, endangered species, Aboriginal heritage ... almost anything," Mr Buckley said.

"Some of the complaints were so spurious."

Weather Bureau sources said that had it been operational it would have warned forecasters about the intensity of the storm.

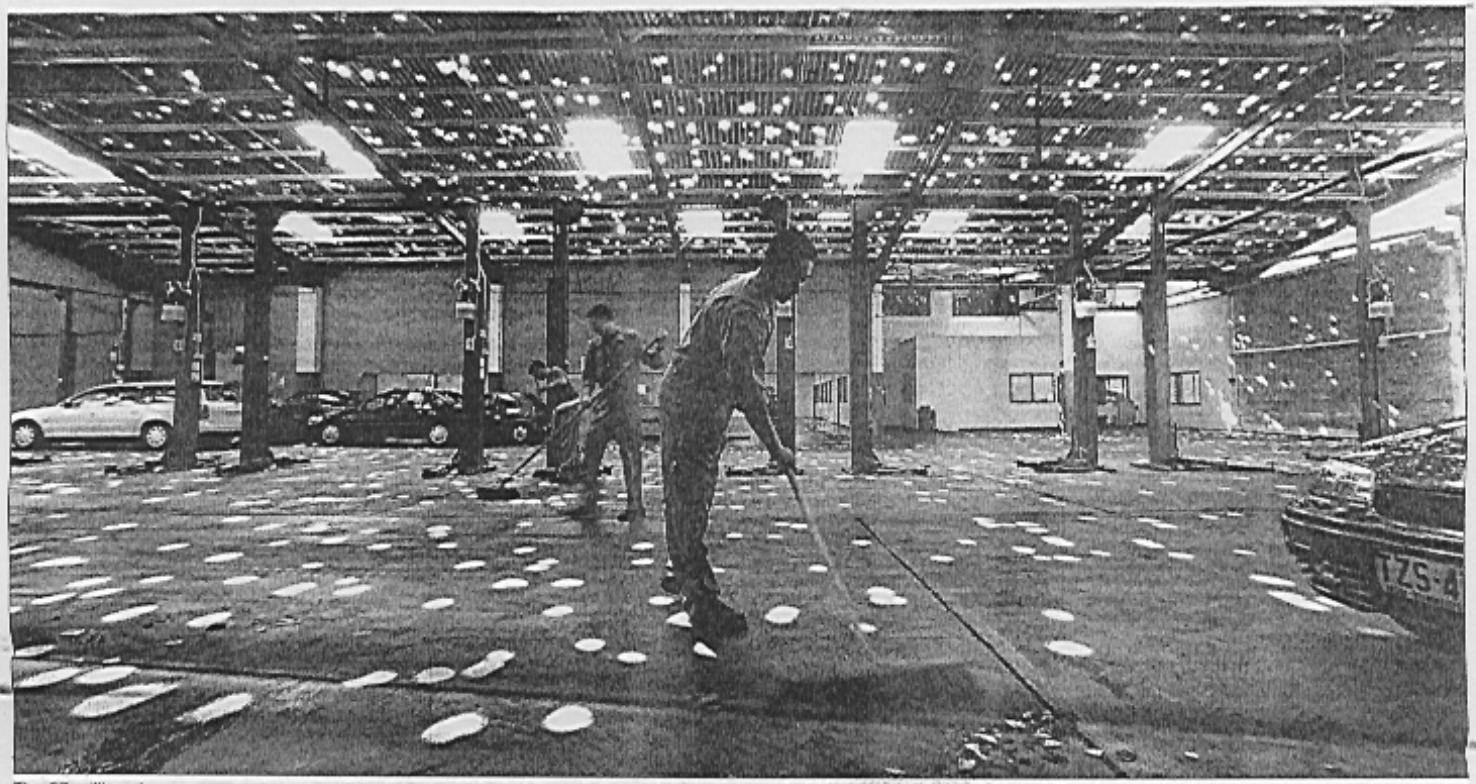
The Doppler, which is designed for severe weather forecasting, uses a system where radio waves are bounced off particles, sending signals back to the radar indicating wind strengths, direction and more importantly the structure and severity of storms.

It has the capability of monitoring a 100km radius and would cover the entire Sydney region. A bureau source said yesterday that had it been installed when it was supposed to have been, enough data would have been available to predict Wednesday's event.

Andrew Treloar, manager of the bureau's severe weather section, said he was only just going through training on the Doppler system.

"It's only been operational for a short period and I am still progressing through a training course for that. It is not fully operational but the important thing is that the system is there," he said.

disaster zone



The $7 million clean-up . . . sunbeams replace the ice which shot through the roof damaging nearly 500 cars at Sutton's Holden at Rosebery yesterday. Pictures: MILAN SCEPANOVIC

but 2km away Doody St, Beaconsfield, escaped relatively unscathed.

The south and north were most seriously hit, although the pattern was bewildering — Alexandria was wrecked while three suburbs away Canterbury was almost untouched.

Botany, Randwick, Waverley, Woollahra, South Sydney and Marrickville have been assessed by the State Government as the worst affected areas, directly affecting about one million people.

Emergency services have been swamped, unable even to keep up with demand for tarpaulins, and there are fears unscrupulous traders will try to profit from the misery.

The Insurance Council of Australia said the insurance payout would surpass the $300 million high of March 1990 Sydney storms, until now the most costly hailstorm.

Council corporate affairs manager Rod Frail said preliminary indications showed claims of at least $350 million.

Yesterday Premier Bob Carr declared a natural disaster covering a 15km-wide area from north of Nowra through to Sydney's northern beaches.

"It is sometimes claimed that Sydney's size has meant we've lost our sense of community — the events of the past 20 hours have put paid to that notion," Mr Carr said.

Mr Carr said 600 State Emergency Service and Rural Fire Service volunteers had worked around the clock to provide shelter.

Yesterday, Sutton's Holden at Rosebery was left with one of the storm's biggest damage bills — estimated by principal Mark Pitzgerald at $7 million.

The legacy of the storm is likely to last for months — there are shortages of basic building materials and car repair centres predict waiting lists of up to six months for panel beating.

Hundreds of interstate tradesmen are expected to converge on Sydney building and prices are tipped to skyrocket.

Editorial: P10

Some of the damaged cars at Sutton's yesterday

Cover blown

THE share market was also damaged by Wednesday's hailstorm.

Share prices fell yesterday by as much as one per cent as the $350 million damage bill was added up.

AMP, which owns a majority of insurer GIO, fell by 18c, closing at $18.16.

Colonial fell 16c to $6.03 while GIO itself dropped 2c to $4.49.

Major delays as aircraft grounded

By SARAH STOCK

IT WAS the worst disruption to Sydney airline services for at least a decade, affecting travel plans of thousands of people.

Suffering the same fate as cars on Sydney streets, 23 Qantas and Ansett planes were withdrawn from circulation yesterday because of hail damage.

The damage is expected to cost the airlines millions of dollars in lost revenue and repairs.

Airline representatives said the damage to planes was relatively minor. But they said safety checks and repairs were being made to ensure there was no internal or structural damage to planes.

"We've never had anything like this," an Ansett Australia representative said.

"Usually with cyclones the damage is less than this because we have warning and can move the planes to other ports."

"This was such a freak storm there was no way we could have seen it coming."

Aircraft consultant David Howells, a pilot with Qantas for 35 years, said even simple dents could affect panel fastenings.

Any breach in the fabric could affect the structural integrity of the plane, he said.

Ansett cancelled 17 domestic flights yesterday after taking seven planes out of operation.

Qantas cancelled 20 domestic flights after taking 14 of its planes out of service and said many international flyers could expect delays of at least a couple of hours.

Both airlines had approximately 10 per cent of their planes out of operation.

Ansett Australia had three 767s, two Airbus 320s and two Boeing 737s undergoing repair.

Travellers expecting to fly in the next few days are advised to check their bookings as both Qantas and Ansett are uncertain when operations will return to normal.

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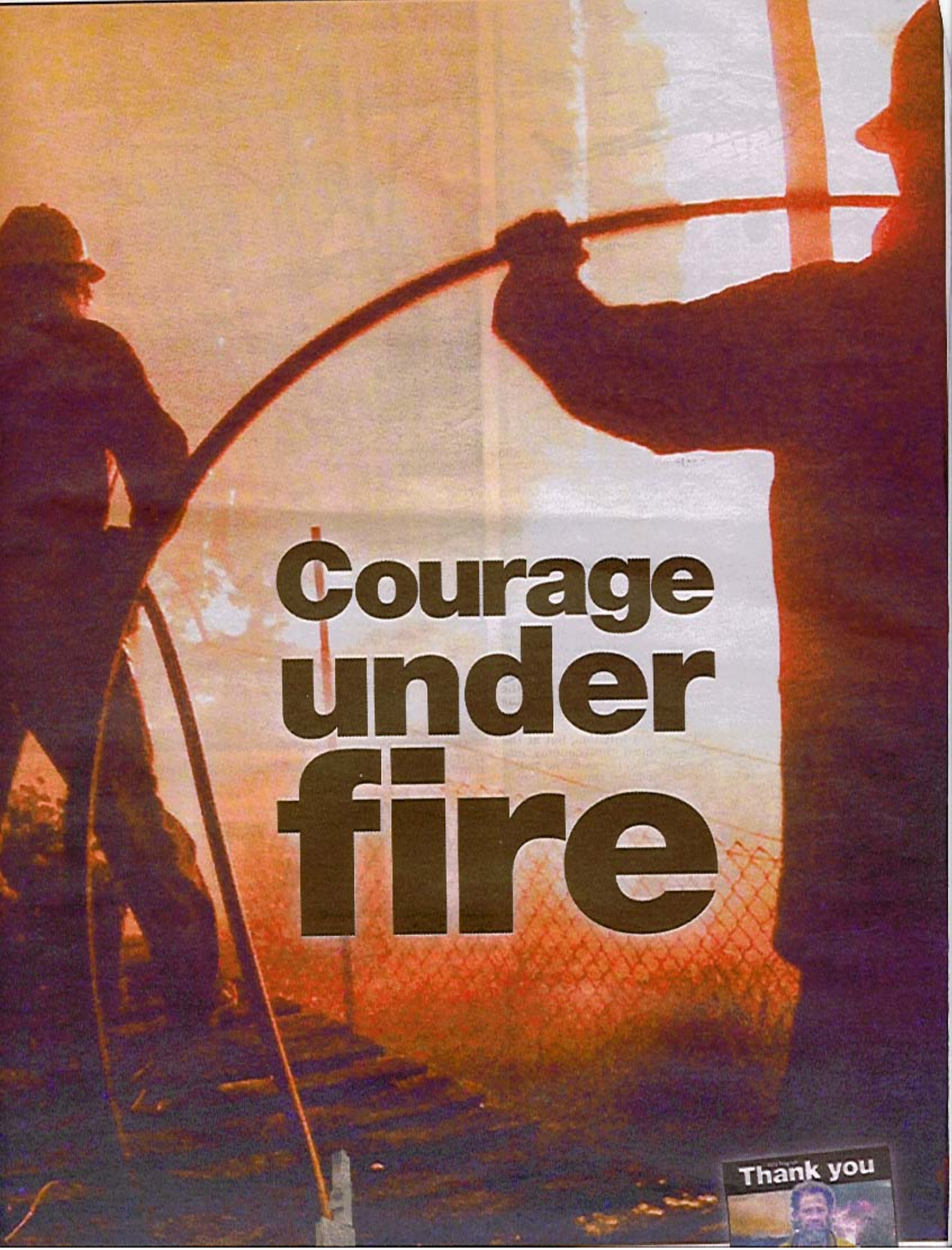
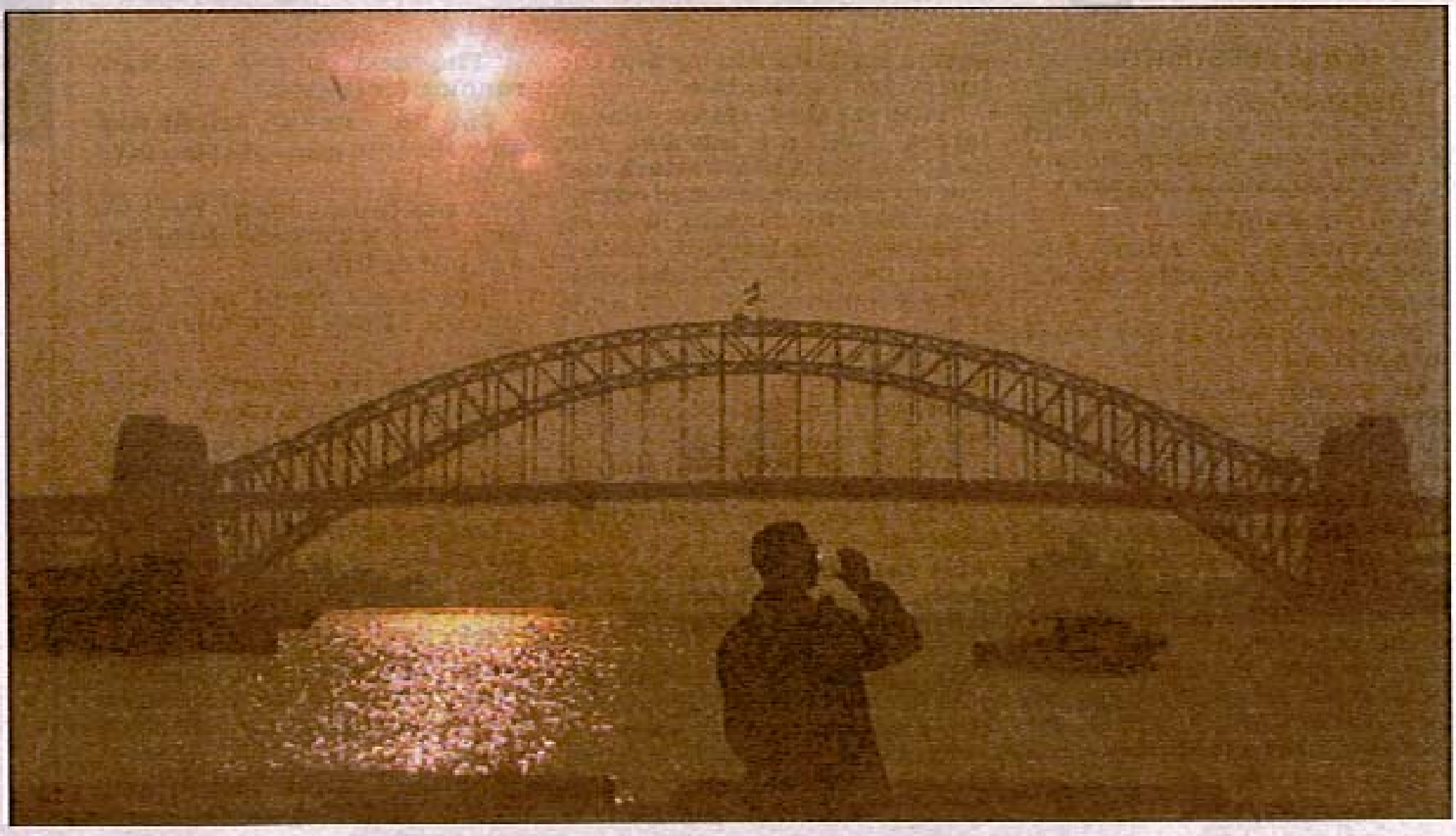
Searing summer

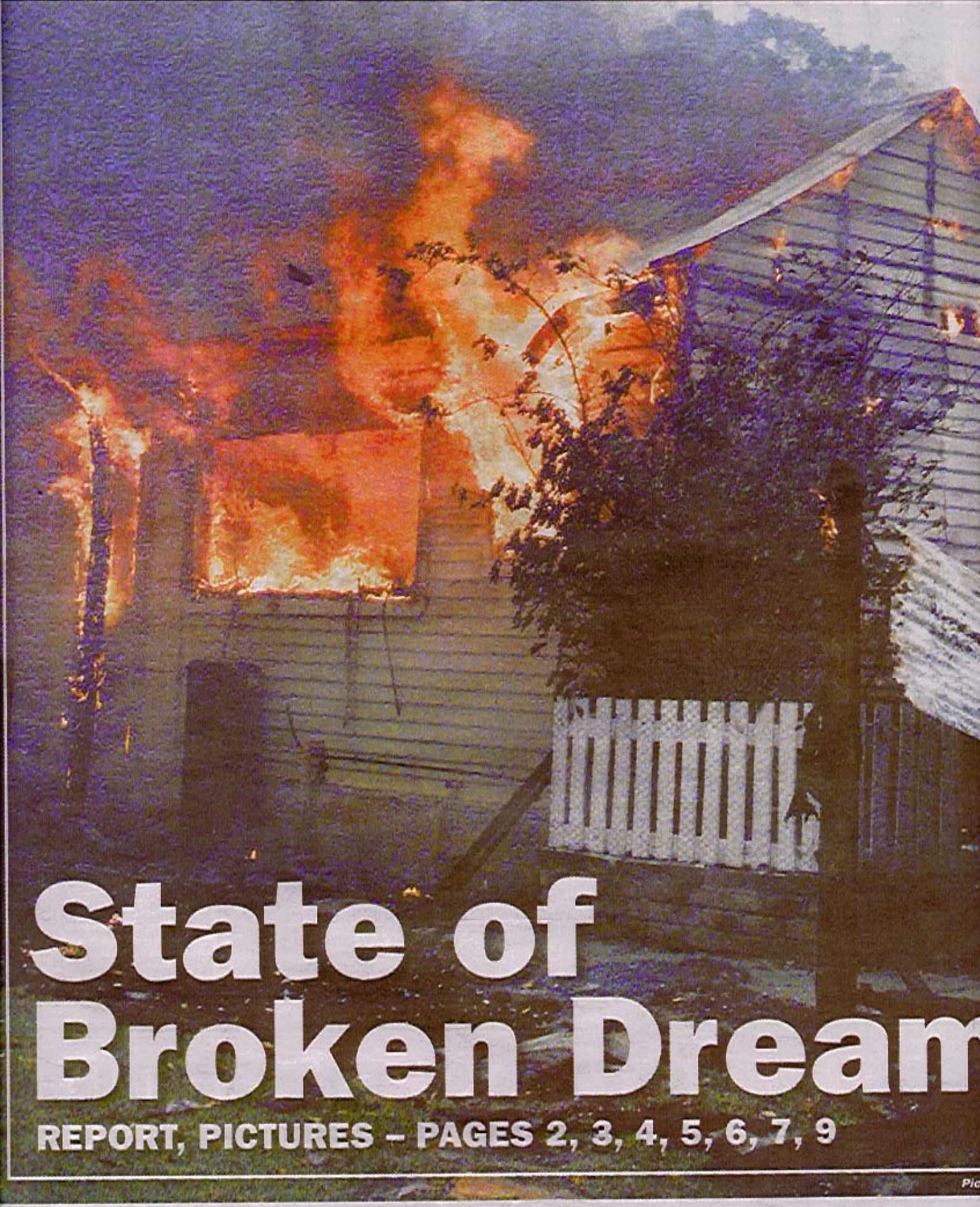
The bushfires that erupted in NSW on Christmas Day saw firefighters rally from around the country to defend homes and communities as the flames raged on many fronts. It was just the start of a frightening fortnight of fire.

Fire front: a huge column of smoke billows across the Great Western Highway at Penrith, western Sydney, as a grass fire at nearby Luddenham, top left and right, sees farmers race to free livestock

Courage under fire







State of Broken Dream

REPORT, PICTURES – PAGES 2, 3, 4, 5, 6, 7, 9

Pic

MEET TEAM GRUND

THE
Daily Telegraph
Friday, December 28, 2001
90 cents*
Including GST M

BLACK CHRISTMAS FIRES: DAY 4

Anatomy of the fires

First 24 hours

Second 24 hours

Crown fires

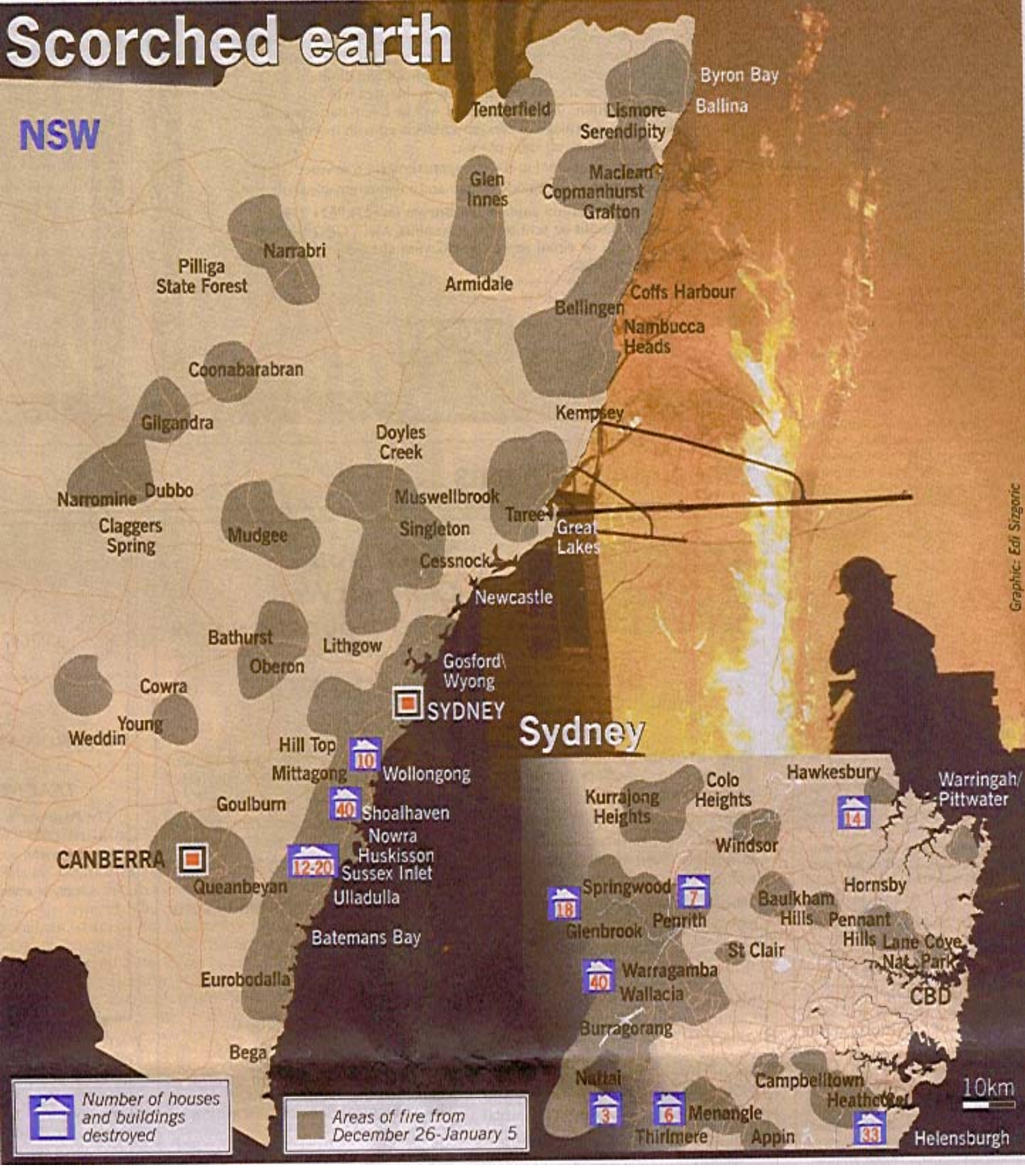
- Crown fires are rapidly spread by wind and jump from tree to tree
- During a crown fire, tree explosions occur as clouds of evaporating resin suddenly reach ignition point

- Trees burst open, shooting out burning oils and setting off chain reactions of flame
- Crown fires can move at speeds well over 200km/h
- Australia is the most fire-prone country in the world because of the abundance of oils in native trees

How a fire jumps a river

A flow of embers is carried upwards by thermal currents, then drops on to trees, and starts spot fires, which can develop into major fires. Superheated air currents flowing around the area make it easier for embers to start spot fires. On Christmas Day, embers were being carried 8km ahead of fire fronts. Usually embers fly only a few hundred metres.

Scorched earth



Graphic: Edi Sizgoric

Saturday, December 29, 2001

$1.30 Including GST M

BLACK CHRISTMAS FIRES

PREPARE FOR A DAY FROM HELL

Hell on high water

Raging sea . . . Nicorette battles heavy seas off the NSW South Coast yesterday. Nicorette had picked up six places late last night. Picture: IAN MAINSBRIDGE

Twister leaves Ingvall crew in shock

By AMANDA LULHAM

EMOTIONAL Ludde Ingvall said footage of his yacht being slammed by a mini-tornado during the first night at sea in the Sydney to Hobart had bought "tears to his eyes" when he and his crew viewed it yesterday.

The memory of the terrifying experience was still fresh in Ingvall's mind last night despite it being 24 hours since 100-knot winds within a water spout/tornado slammed his 80-footer off the NSW South Coast.

"We are all still very shell-shocked. We cannot believe what we saw," Ingvall said.

"When we saw the footage of it today it bought tears to my eyes. It was frightening.

"It was so scary I cannot get it out of my mind."

Ingvall said while the yacht had suffered no damage in the assault, his crew were both tired and emotional which had made the second day at sea particularly hard.

"The crew had to work for six hours solid after the twister hit us," Ingvall said.

"That meant for some of them that they did not sleep for over 20 hours because they missed their watches.

"If the crew had said after the twister 'let's go into Jervis Bay and get a coffee' I would not have argued with them.

"But they wanted to keep going and we have not given up hope of winning the race.

"We are all just a bit tired and shell-shocked right now."

Ingvall said he had seen the water spout approaching and had time to pull all Nicorette's sails down and send as many of his crew down below as possible.

Large hailstones which fell during the drama at the sea and the cyclonic-force winds devastated Nicorette's new racing mainsail and deprived her of leading the Sydney to Hobart fleet south.

"We have now been forced to put up our cruising mainsail which is about four years old and just used for deliveries so is a lot slower."

Incredibly the twister claimed just one race casualty with Australian Skandia Wild Thing sent to the sidelines with sail damage after being pummelled by 60-knot winds.

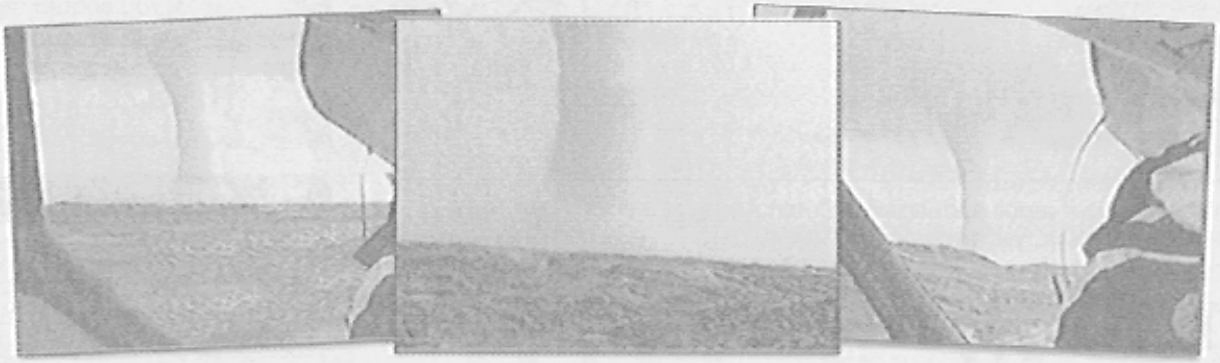
However hardened and veteran skippers in the fleet were still talking about the incredible phenomenon yesterday.

Team News Corp, one of the round the world racers competing in the event, missed the full force of the twister but sustained minor damage as a result of the associated strong winds.

"It was the most unbelievable sight and nothing like anyone has experienced before," said Team News Corp navigator Ross Field yesterday.

"A water spout/tornado came through illbruck, Assa Abloy and ourselves giving us winds up to 58 knots.

"It was really scary to see these long vertical round spinning clouds charging towards us with the bottom sucking up water. There was just nowhere to go."

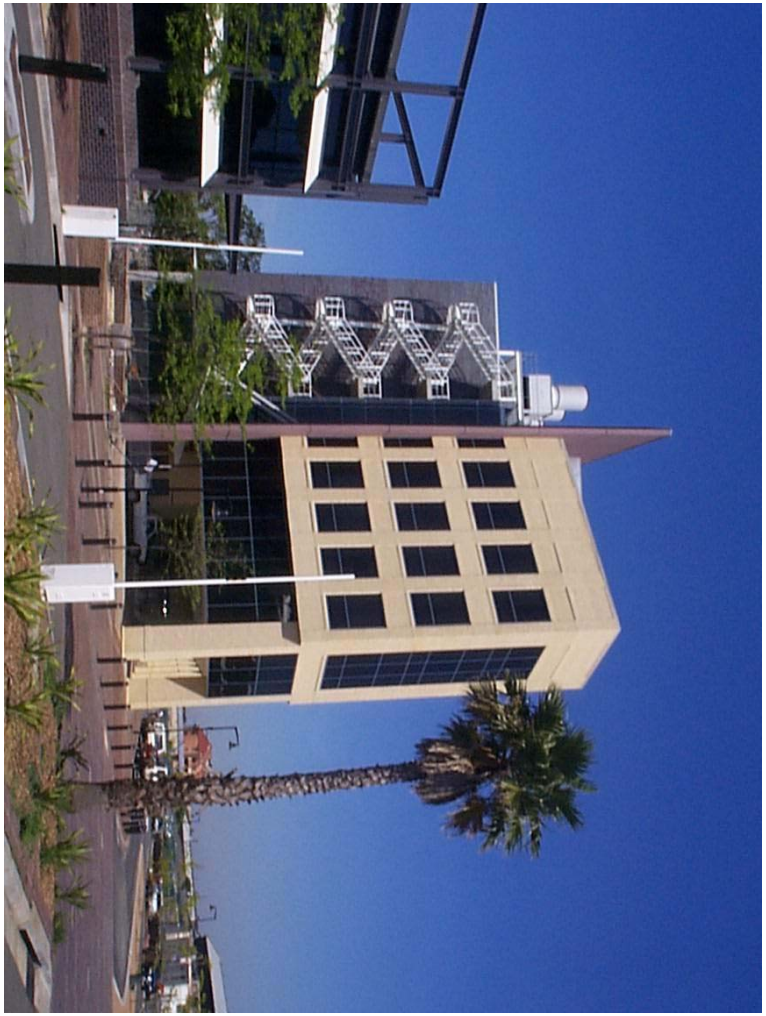


Fury at sea . . . the tornado that rocked the fleet on Wednesday night

■ TEAM News Corp meteorologist Nick White explains what occurred during the first night at sea in the Sydney to Hobart: "A water spout is a tornado that forms over water. It occurs under a severe thunderstorm and in the presence of cumo-nimbus clouds. There is a potential for wind speeds of hundreds of kilometres an hour at the centre of the spout. The tornado was unexpected and violent. Hot winds came off the mainland and mixed with the seabreeze to cause the phenomenon."

Four-page special on The Great Race: Pages 102-105

Load Supply Areas
Johnnson & Johnson Research Critical Energy Supplies
3rd Floor Bio-Medical Building



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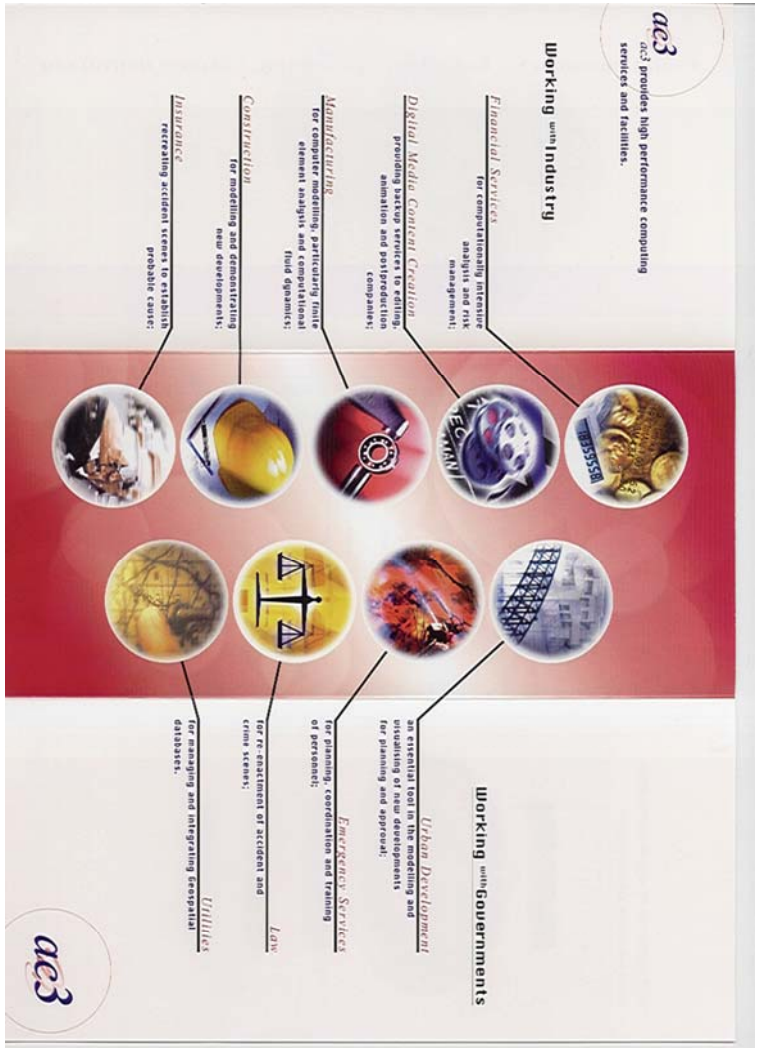
Supply to Super Computer



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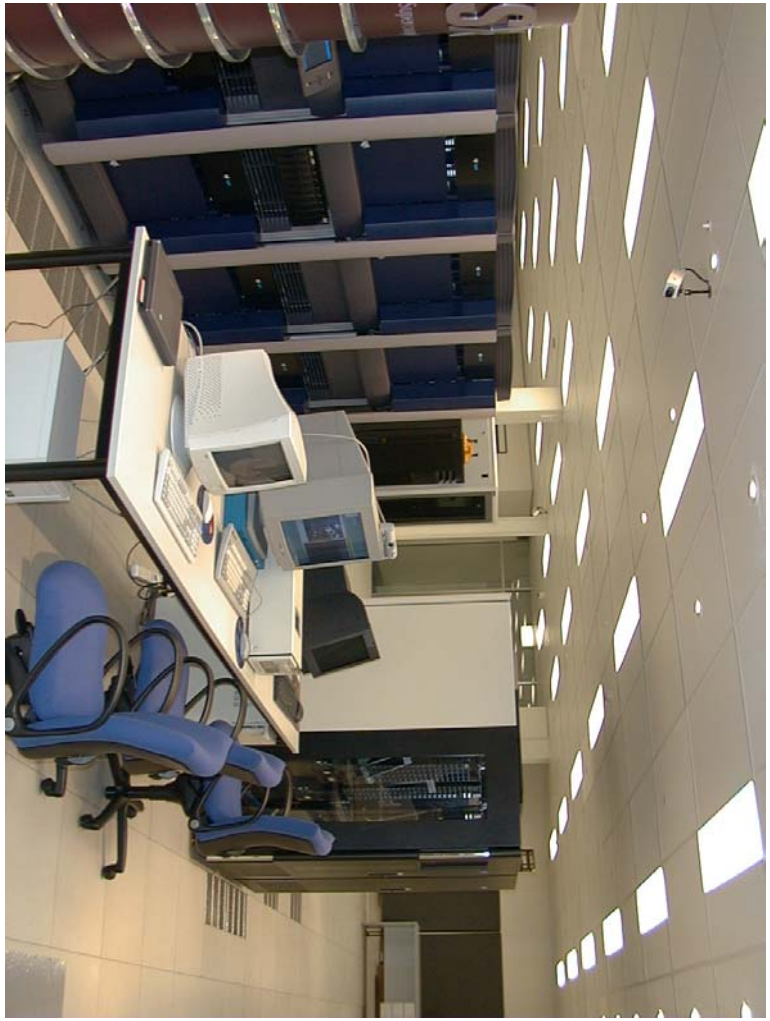
Super Computer Installation Supplied by Fuel Cell



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EcoTechnoHabitat Hotel

WELCOME TO THE 21ST CENTURY!

The EcoTechnoHabitat(ETH) Hotel due to open its doors in mid-1999 is a signature building of Ipandco Development Pty. Ltd. Situated at the Australian Technology Park (ATP) Eveleigh, Sydney, the hotel will be the first of its kind in Australia. The design reflects the innovative vision of the founder whose concept is to break away from the conventional hotel equipped with traditional amenities to a design for the 21st. Century, incorporating advanced ecological and technological sciences. The ETH will provide a focal point at the ATP encouraging the interaction of ideas between researchers, guests, visitors and the public sector.

Ecology

Ecological features of the ETH are to include the use of available natural lighting, ventilation, environmentally friendly building materials and the use of fuel cell as an alternative clean and efficient energy source. Other Green initiatives are the EcoTechno Research Centre that will monitor the performance of technologies and materials incorporated in the building and the Aeroponic and Hydroponics Centre encompassing an on going study of ecology among which includes a seed saving programme.

Technology

Hotel guests will have access to the world leading IT & T infrastructure installed at the ETH, in both their rooms and the business centre within the hotel. This will provide services such as video, data and voice communications; Information including car hire, airlines and tour bookings; On-line shopping; Complete on-line banking services; Electronic commerce i.e. guest information regarding room accounts; Full browsing & E-mail on the Internet; Computer application servicing; SmartCards and In-house guest liaison & Technology support services. (April 1998)

Ipandco Development Pty. Ltd Suite 201, NIC, Australian Technology Park, Eveleigh NSW 1430. Tel. 9209 4514 Fax. 9310 5083 Email: Info@Ipandco.com.au http://www.Ipandco.com.au
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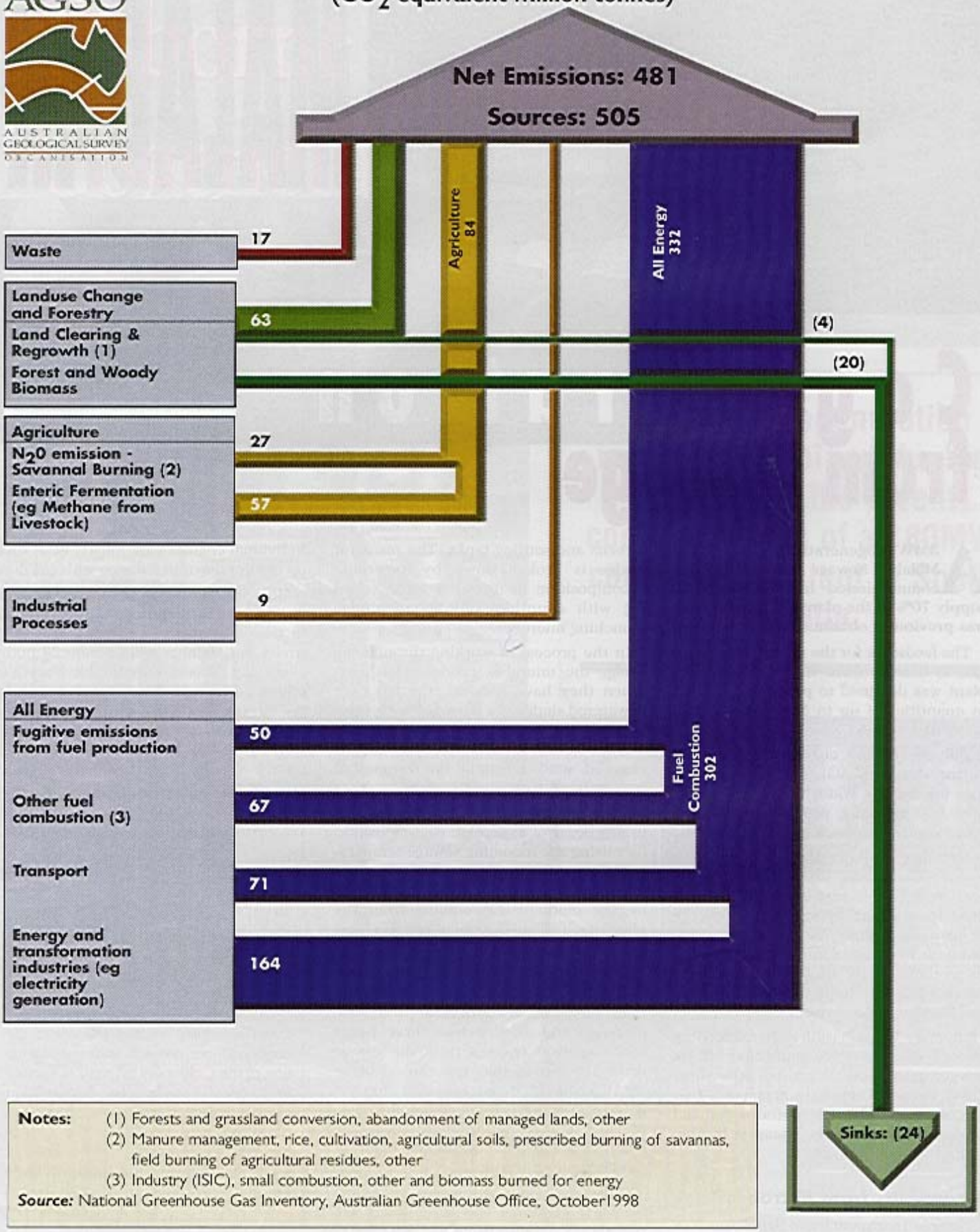
Australian Greenhouse Gas Emissions 1996

(CO_2 equivalent million tonnes)



Notes: (1) Forests and grassland conversion, abandonment of managed lands, other
(2) Manure management, rice, cultivation, agricultural soils, prescribed burning of savannas, field burning of agricultural residues, other
(3) Industry (ISIC), small combustion, other and biomass burned for energy

Source: National Greenhouse Gas Inventory, Australian Greenhouse Office, October1998

ENERGY IN NEW SOUTH WALES 1999

MINISTRY OF ENERGY AND UTILITIES

Web site http://www.doe.nsw.gov.au

The Snowy Hydro-Electric Scheme provides another 3,756 MW of potential capacity, which is traded between NSW and Victoria through the National Electricity Market.

NSW has a large resource of coal seam methane, some of which is being used for electricity generation. Two coal seam methane power stations exist in NSW: a 54 MW station at the Appin Mine, south of Campbelltown, and a 40 MW station at nearby Tower Mine. A privately owned company, the Sydney Gas Company is proposing to apply a coal seam fracturing technique pioneered in the US to make production of coal-seam methane gas in the Sydney basin feasible.

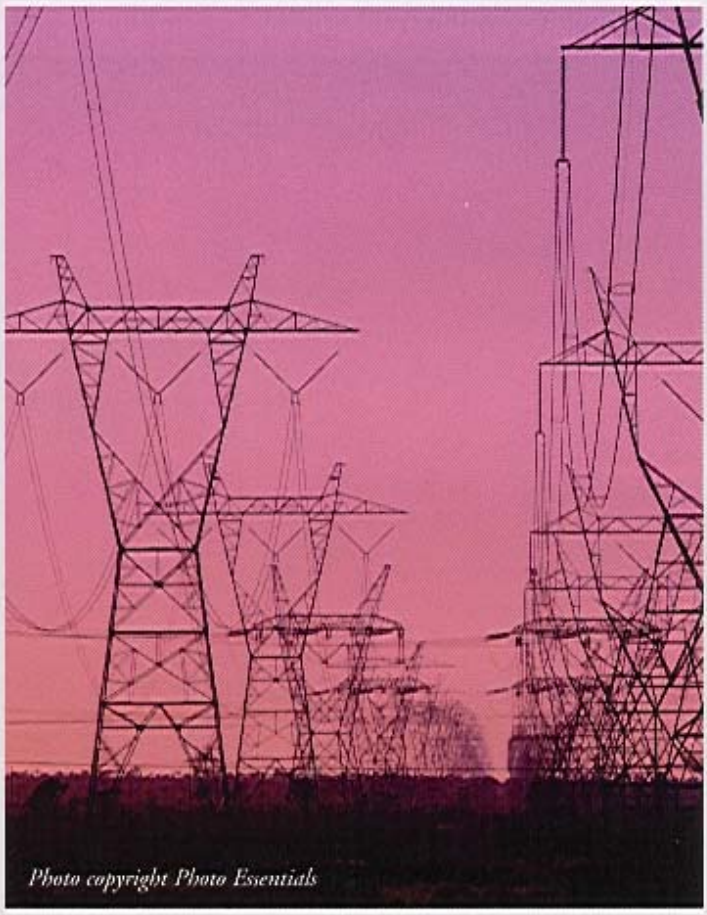


Photo copyright Photo Essentials

Methane, resulting from the decomposition of organic material in green waste disposal areas, is another source of energy for generation. Energy Developments Pty Ltd own waste tip methane based electricity generation plants at Belrose and Lucas Heights with a total capacity of 22 MW.

Energy can be generated from municipal waste by controlled combustion or gasification followed by combustion. Energy Developments Pty Ltd is constructing a solid waste energy recycling facility at Wollongong that will use unsorted household garbage to generate electricity.

Cogeneration

Cogeneration involves the generation of combined useful heat and electricity from a single fuel. NSW has around 306 MW capacity of cogeneration. The largest is the 162 MW gas fired cogeneration plant supplying Visy Paper's recycling facility at Smithfield. The three sugar mills in northern NSW (Broadwater, Condong and Harwood) each have bagasse cogeneration plants with a total capacity of around 18 MW. A 2.4 MW cogeneration unit fuelled by methane from sewage treatment was opened in August 1999 at the Malabar Sewage Treatment facility.

There is potential in NSW for natural gas to be used in generating electricity. A number of gas fired power plants are under investigation for NSW including a 350 MW combined cycle plant on the western shores of Lake Illawarra (site of the old Tallawarra power station), a 100 MW plant at Wagga Wagga, a 420 MW gas cogeneration plant at Kurnell and a 350 MW gas cogeneration plant at Botany. However, these are not likely to proceed under the existing pricing regimes for electricity and gas.

Transmission

TransGrid (the NSW electricity transmission authority) is the state owned corporation responsible for the management, operation, control and maintenance of the State's high voltage electricity system.

TransGrid manages about $2 billion worth of assets. Its transmission system comprises 11,507 circuit kilometres of transmission lines, 20 circuit kilometres of underground cables and 73 major substations and power station switchyards that operate at voltages up to 500 kV.

With commencement of the National Electricity Market, the National Electricity Market Management Company (NEMMCO) has become the national market system operator. The National Electricity Code Administrator (NECA) administers and enforces the National Electricity Code.

NEMMCO is also responsible for system security. Regulation of transmission pricing and access has been transferred from the Independent Pricing and Regulatory Tribunal (IPART) to the Australian Competition and Consumer Commission (ACCC).

A commercial trading link between the NSW and Victorian wholesale markets commenced in May 1997 allowing generators in either State to participate in the interlinked wholesale markets.

Construction has begun on the Queensland-NSW Interconnection, a 550km (220 km in NSW) double circuit 330kV transmission line from Armidale in NSW to Tarong in southern Queensland. This proposal is scheduled for completion in October 2001. In addition, a DC interconnection between Queensland and NSW, Directlink, is being constructed by NSW distributor NorthPower and TransEnergie Australia. This facility is expected to come into operation by January 2000. TransEnergie Australia is also proposing Murraylink, a 200 MW DC cable to further link the Victorian and NSW grids to South Australia, allowing additional power to be traded between the states. TransEnergie aims to have Murraylink in operation by January 2001.

ELECTRICITY

Electricity is a derived fuel. In 1997-98, electricity accounted for 18.8 % of the 'end-use' energy consumed in NSW.

Generation

The total generation of electricity in NSW for 1997-98 was 57,535 gigawatt hours (billion kWh). NSW imported 6,677 gigawatt hours of electricity from the Snowy Mountains Hydro Electric Scheme and Victoria. Also during this year, NSW exported 2,992 gigawatt hours, mainly to the ACT but also a small quantity to Victoria.

The electricity supplied in NSW comes mainly from coal-fired power stations (92 percent). Hydro electricity (both the Snowy Mountains Hydro Electric Scheme and other small hydros) represents almost 5% of NSW supply. The remainder comes from gas-fired plants and other renewables.

Installed capacity of the principal generating plants (excluding Snowy) in NSW totals approximately 12,909 MW. The maximum demand in NSW during 1997-98 was 10,996 megawatts, an increase of 432 megawatts on the previous year. The average demand was 7,186 MW, an increase of 181 MW on the previous year.

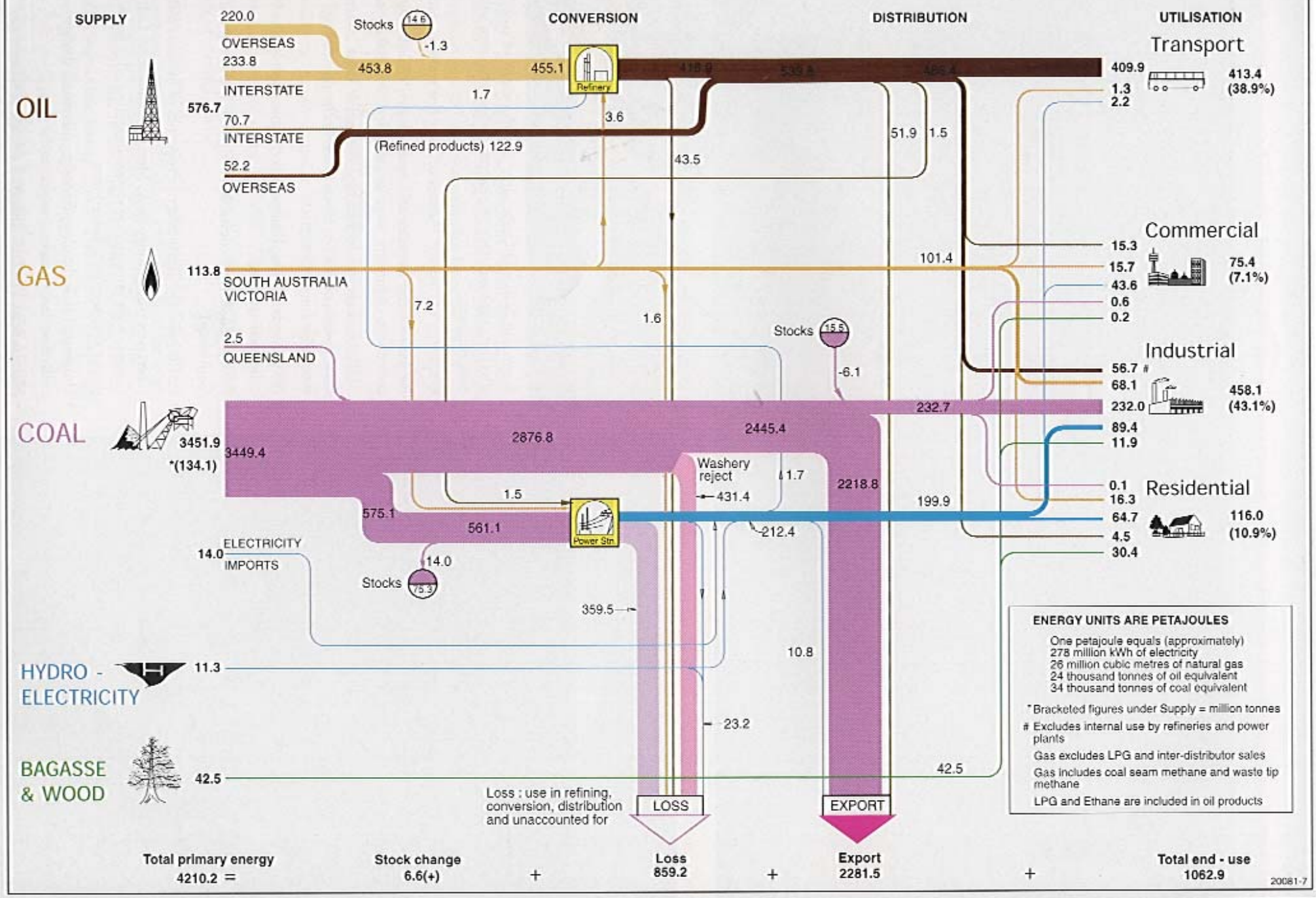
SUMMARY - GENERATION CAPACITY IN NSW
(excluding Snowy)

	MW
Coal	11,520.0
Oil	296.0
Coal Seam Methane	96.8
Cogeneration	305.8
Solar	0.8
Landfill	22.0
Wind	5.6
Hydro	422.4
Hydo pumped storage	240.0
TOTAL GENERATION CAPACITY	**12,909**

Most of the electricity in NSW is generated from coal by the Government owned corporations: Delta Electricity, Macquarie Generation and Pacific Power. In 1997-98, 24 million tonnes of black coal was used to produce electricity.

Photo by David Barnes

NEW SOUTH WALES ENERGY FLOWS 1997 - 98



Electricity Australia 2001

The 54th Annual Report of the Electricity Supply Association of Australia reveals a picture of an industry that's finding its stride after ten years of intense change.

However, as Executive Director of the ESAA, Keith Orchison points out in his introduction to the report, the turbulence the industry experienced in the last decade can hardly be expected to vanish in the new decade. Many challenges still face the electricity industry, particularly given its partially deregulated, and in some cases recently re-regulated situation in each State. The shifting timetables and commitment to deregulation and the progress of competition are notable features for anyone attempting to plan for the future in this industry.

One thing that is certain is that electricity demand is continuing to grow. For the period 1999-2000 total electricity consumption grew by 3.6 per cent. The ESAA forecasts that demand will continue to grow. Even with the most optimistic estimates of a national demand side management and end use efficiency program cutting annual demand growth by half, it is still likely that an additional 30,000 Wh will be needed in 2010. That compares with total existing generation of around 186,000GWh. Ensuring that extra capacity is available to avoid skyrocketing electricity prices, and delivered in a manner that does not produce another 30Mt of greenhouse gases, is the core of the challenge for industry and government.

"As an industry with an aggregate annual turnover of more than $20 billion, contributing value adding of more than $10 billion to the economy and employing more than 30,000 people," Keith Orchison points out. "Electricity supply is of fundamental importance to Australia in its own right.

"The contribution it makes to economic viability and the national standard of living through relatively low cost and highly reliable power supply can only really be appreciated when one observes the problems that ensue, for example in California, when the system breaks down," he said.

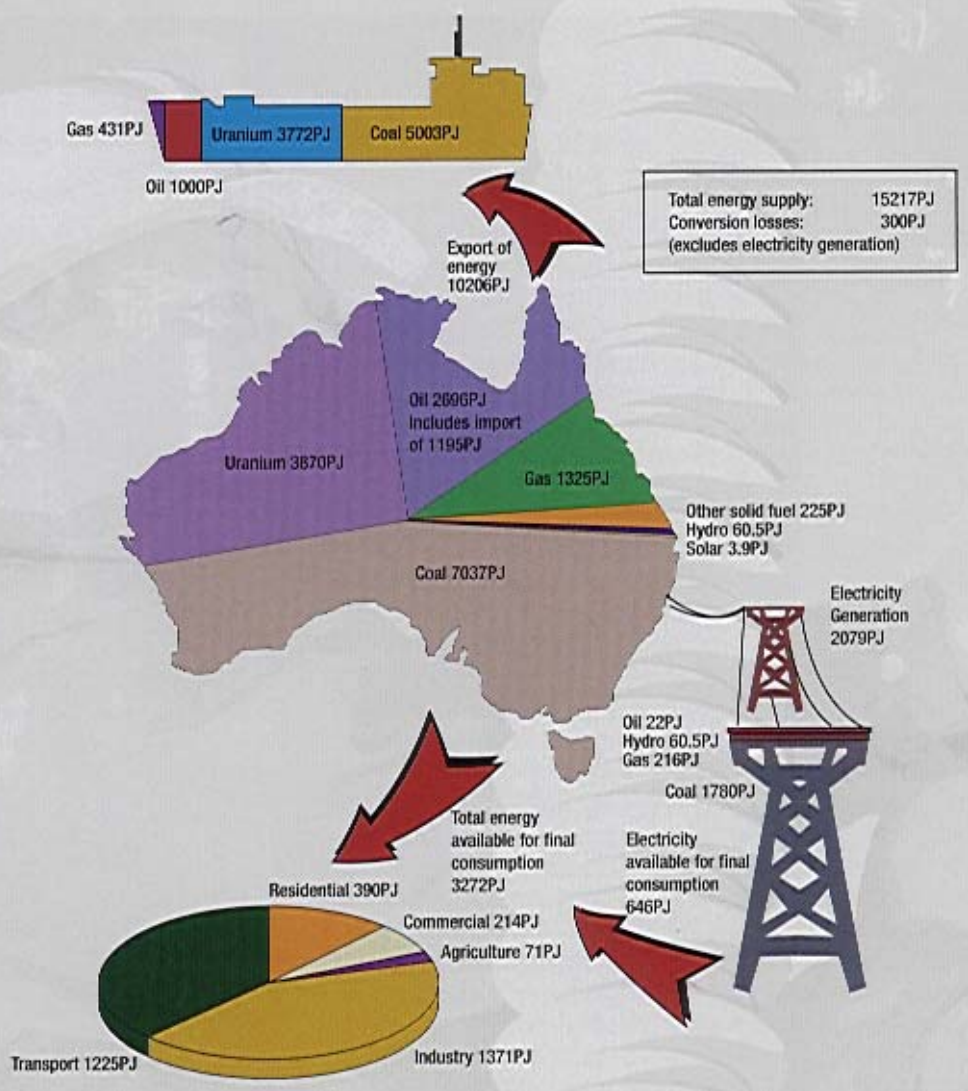
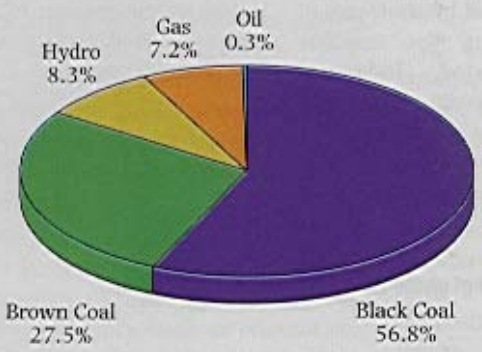


Figure 1: Total energy supply — Australia 1999/2000

Figure 2: Electricity generation by fuel type 1999/2000



"The importance of averting such situations can hardly be over-emphasised and it is now timely for a substantial review of all the factors impacting on the efficiency of the national electricity market."

GROWTH IN ELECTRICITY SUPPLY 1999-2000

Queensland was the fastest growing region with consumption increasing by 6.7 per cent, double the growth rate of most of the other States. Growth in South Australia continued to be very strong, adding another 5.6 per cent to the State's demand. The SA peak demand continues to exceed local generating capacity and the State electricity supply system urgently needs new capacity to ensure reliable supply.

Installed generation capacity in the national system increased by only half a percent in the period. Total installed capacity in the major grid systems is just under 41,000MW. However there are proposals for more than 2,000MW in new generating capacity in southern States, Victoria and South Australia.

NEM DEVELOPMENTS

With completion of DirectLink and the Queensland-NSW Interconnector (QNI) in the second half of 2000, all current regions of the NEM are interconnected. Plans to include Tasmania in the NEM through an undersea cable (BassLink) are also being pursued.

There are also plans to boost the transfer capacity from the Snowy region to Victoria to cope with increasing peak demand in summer. In Queensland the previous low reserve position is changing to one of excess reserve in the near term.

Figure 3: Final electricity consumption by sector 1999/2000

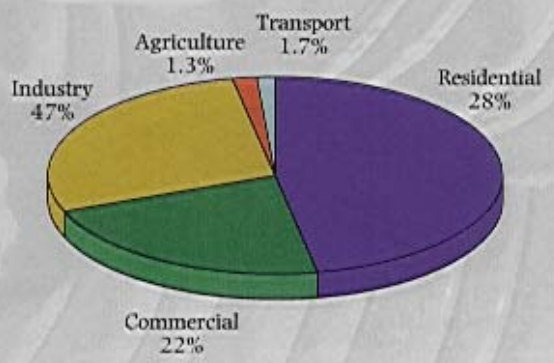
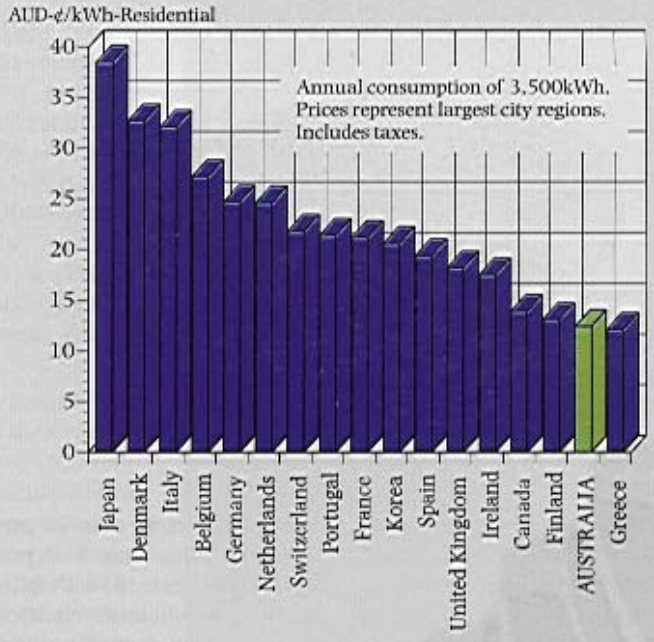


Figure 4: International electricity prices — January 2001 Residential



ELECTRICITY PRICES

Wholesale electricity prices continued to increase in NSW, Victoria and South Australia but decreased in Queensland. South Australia had the highest electricity price in the national

Figure 5: International electricity prices — January 2001 Industrial

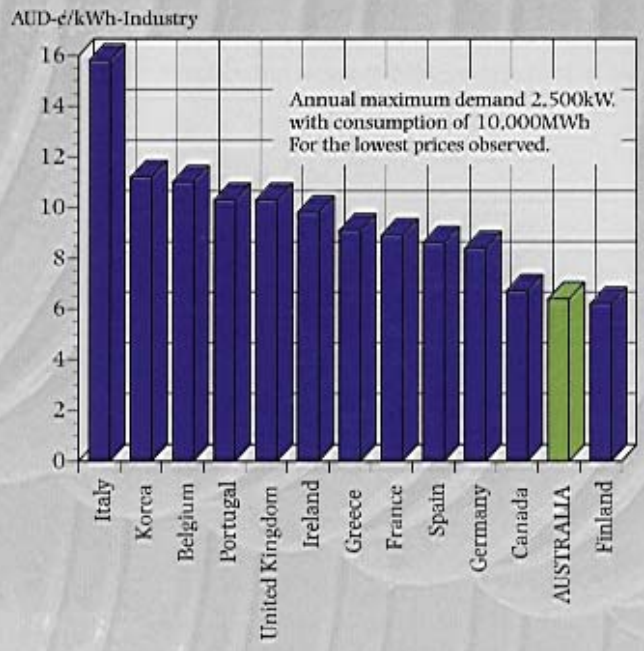
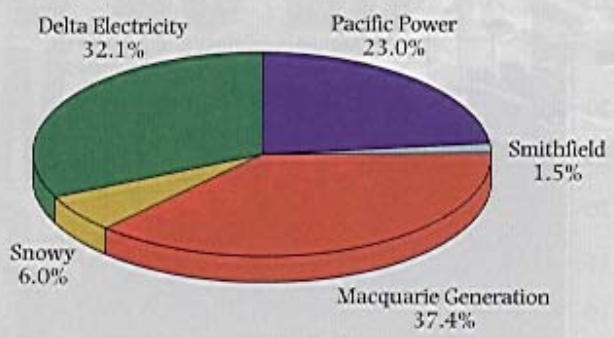


Figure 6: Market share 2000, NSW generation



electricity market in the year under review, averaging nearly $70 per MWh, more than double that of NSW and Victoria. The higher prices in South Australia are attributed to the current tight demand-supply situation in the system. With peak demand exceeding the total local generating capacity and present limits on interconnection capacity, SA prices are expected to stay high in the near term.

Queensland recorded a wholesale price reduction in the period as new generating capacity was added. Wholesale prices decreased by more than 20 per cent from more than $63 per MWh to just under $50. Despite increases in wholesale electricity prices, retail electricity prices increased only marginally in NSW and Victoria. In Queensland, retail customers enjoyed a 5 per cent reduction in the cost of electricity.

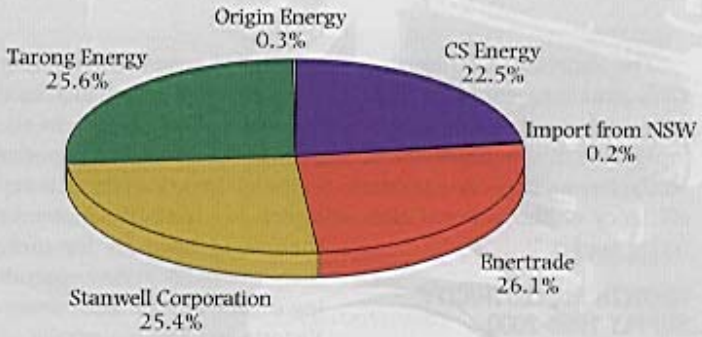
SUPPLY RELIABILITY

The national average period customers were without electricity supply because of interruptions increased by seven minutes to 4 per cent per customer. Most of the increase is attributable to events in South Australia and Western Australia. South Australia was mainly affected by shortages of supply during the summer peaking period. Industrial action and severe storms had impacts on the supply reliability of the Western Australian system. The average number of interruptions to each customer increased by 14 per cent despite the average time for restoration or power after interruption decreasing by more than six minutes.

SAFETY

Overall lost time injury frequency continued to decline. The generation and distribution sector improved safety performance while the transmission sector did not manage to match the very good performance of the previous year.

Figure 8: Market share 2000, Queensland generation



EMPLOYMENT IN THE INDUSTRY

Employment decreased by 2.3 per cent. The majority of the reduction came from South Australia (down 22.2 per cent) and Western Australia (down 16.6 per cent). ■

Figure 7: Market share 2000, Victorian generation

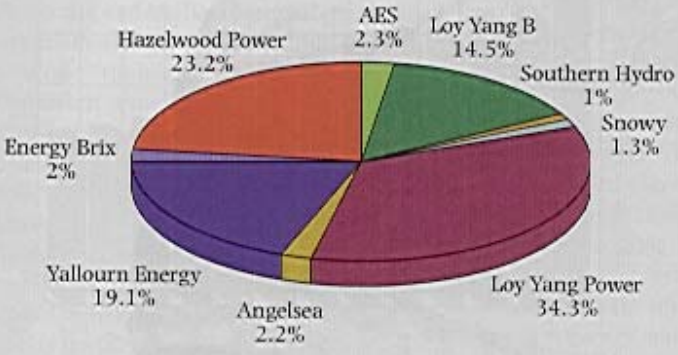
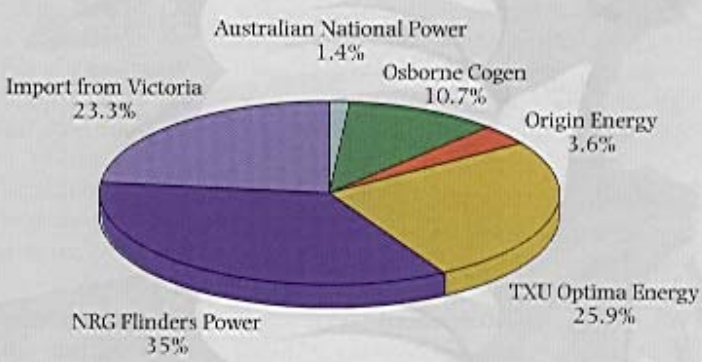


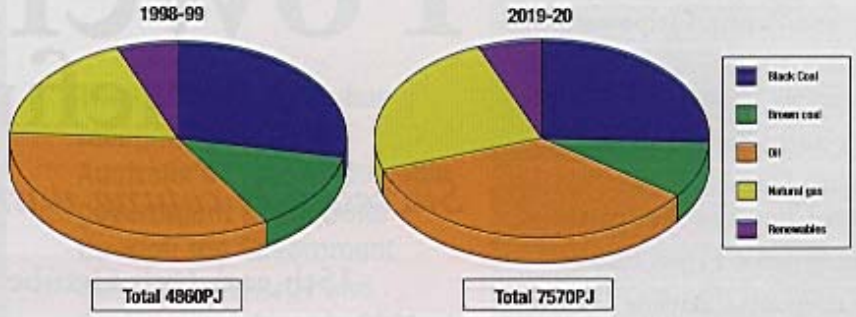
Figure 9: Market share 2000, South Australia generation



ABARE
Australian Energy Outlook to 2019/20

The Australian energy sector has changed significantly over the past 25 years. While many of the trends established in this period continue, market reforms and new opportunities, both domestic and international, are stimulating a fresh set of changes the results of which we will only see in coming years. In October ABARE will release its latest assessment of long term trends in Australian energy consumption and production, extending the outlook horizon to cover the period between 1998-99 and 2019-20. This article draws on preliminary results from the outlook and readers should note that the final results to be released in October may differ.

Primary energy consumption, by fuel



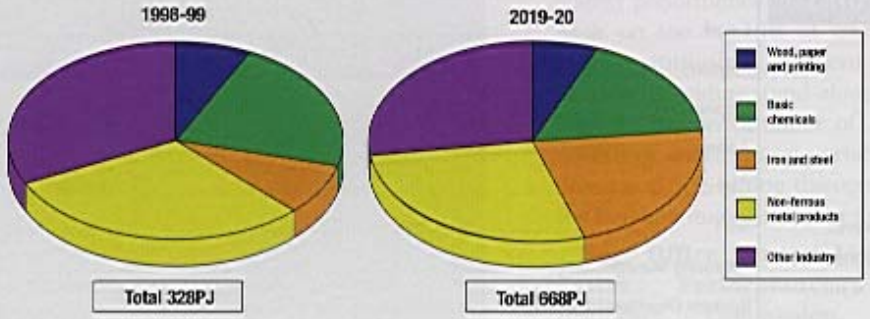
ABARE and its predecessors have published long term projections on a biennial basis for more than 25 years. In this cycle ABARE developed a fundamentally new approach (for ABARE) to forecasting long term energy consumption and production trends, placing particular emphasis on adopting an integrated analysis of the electricity generation sector within an Australia wide domestic energy use model. The new forecasting model has been called E4cast — alluding to its primary role as an energy forecasting tool — and ensures crucial economic and engineering principles are brought to bear consistently and transparently, on the estimated long term trends.

One of the key messages in this outlook is that Australian energy consumption is forecast to continue to grow strongly over the medium term, averaging around 2.0 per cent a year to 2019-20. Total energy consumption in Australia is estimated to have grown by 2.5 per cent between 1973-74 and 1998-99, far outstripping that in the OECD, which is estimated to have grown at an annual rate of only 1.4 per cent over the period 1971–95. At this forecast rate of growth, primary energy consumption in Australia would be equivalent to some 315GJ per person in 2019-20: for comparison, average energy consumption per person in the United States, in 1998, was 339.5GJ while the average for the OECD as a whole in the same year was 193.9GJ.

Economic growth is far and away the major determinant of Australia's rising rate of energy consumption and in the medium term Australia's GDP is assumed to settle around a trend rate of 3.5 per cent a year. The continued improvement in the efficiency of Australian energy use is reflected in the widening gap between real GDP growth and energy use.

In terms of energy consumption and production, the electricity sector is arguably the most important sector in the Australian context. With an estimated 40 000MW of capacity generating approximately 200TWh of electricity, the sector accounted for almost 43 per cent of total Australian energy consumption in 1998-99. Moreover, Australian electricity has historically been supplied to industry at prices well below that of most other OCED countries, supporting the development of a range of internation-

Natural gas consumption in manufacturing, by subsector

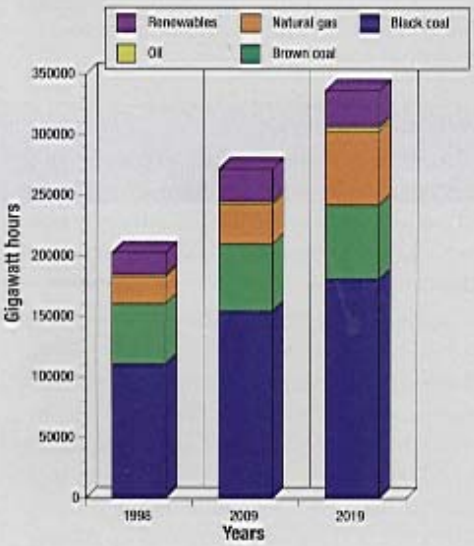


ally competitive, energy intensive industries in Australia.

Over the medium term, the electricity generation sector is forecast to continue to grow strongly, accounting for around 31 per cent of the total projected increase in Australia's primary energy use.

Consistent with the operation of the Commonwealth Government's Mandated Renewable Energy Target, renewable electricity generation totals a little less than 27,500GWh by 2009-10 with biomass (principally bagasse), wind, hydro and biogas all contributing to meet the target. Nevertheless, black coal will continue to provide the lion's share of electricity generation in the foreseeable future with electricity generation from black coal plant forecast to increase by around 70TWh over the full forecast period. This equates to additional capacity of some 9000MW in total, and builds on the 2300MW of black coal fired capacity already committed out to 2004-05.

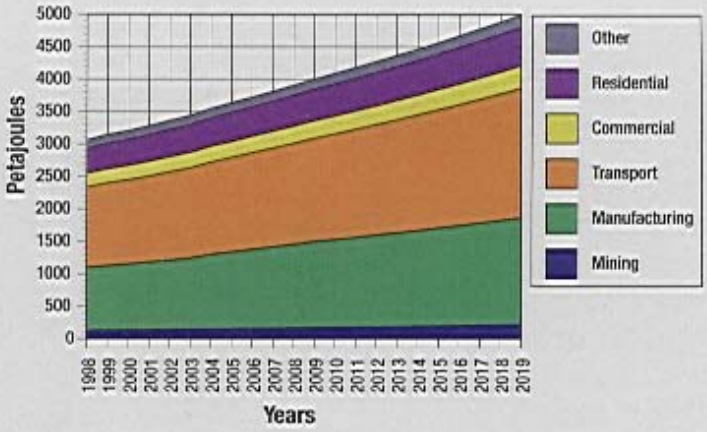
Electricity generation, by fuel



The transport sector and the manufacturing and construction sector (hereafter simply referred to as manufacturing) collectively account for over 72 per cent of total final energy consumed over the outlook period. The transport sector alone accounts for approximately 41 per cent of total final energy use, with around 97 per cent of the fuel mix comprised of liquid fuels.

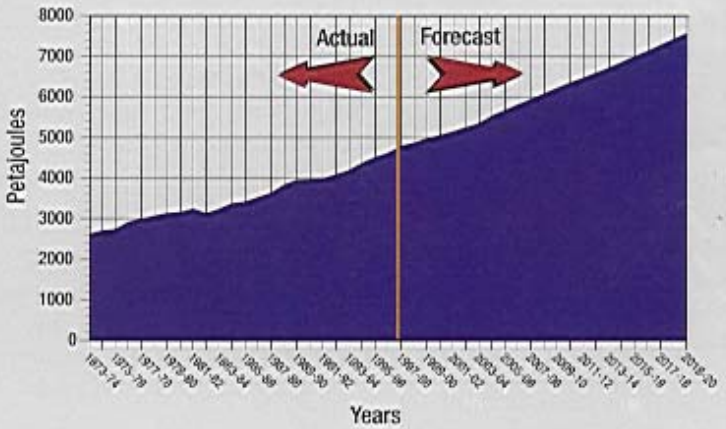
Since the early 1970s, growth in transport sector energy use has averaged around 2.4 per cent a year and over the medium term energy use in transport is forecast to continue to grow at or marginally below this long run trend. The manufacturing sector is also projected to grow by 2.3 per cent a year and is expected to account for almost 33 per cent of the total increase in final energy use and some 70 per cent of the increased use of natural gas. This contrasts with the long term historical growth in manufacturing sector energy use (1.7 per cent since 1973-74) and largely reflects the bullish outlook for the iron and steel and basic non-ferrous metals sectors.

Final energy consumption, by sector



Energy use in the residential and commercial sectors is forecast to increase by 2.1 and 2.4 per cent a year, respectively.

Since the early 1970s the mix of fuels in total energy consumption in Australia has changed radically with the combination of oil price shocks, natural gas discoveries and the development of gas transmission and distribution infrastructure providing the catalyst for significant growth in natural gas consumption at the expense of oil. Between 1973-74 and 1998-99 the consumption of natural gas increased by an average rate of 6.9 per cent a year. Correspondingly, the share of natural gas in total energy consumption rose to 18 per cent by 1998-99 — almost triple the 1973-74 share. Over the medium term, the consumption of natural gas is forecast to continue to grow relatively strongly, at around 3.4 per cent a year. Nevertheless, coal and oil will continue to dominate Australia's energy mix, and collectively are projected to account for some 70 per cent of Australia's primary energy use in 2019-20.

Australia's reliance on imported crude oil is expected to increase over the outlook period with the import share rising to around 52 per cent by 2019-20. On the other hand, Australia's trade balance in refined petroleum products is forecast to remain largely unchanged and reflects the assumption that net (petroleum refining) production capacity within each state will not only be maintained but will continue to expand over the medium term to match projected growth in domestic consumption of petroleum products. ■

Australian primary energy consumption