TRARALGON BYPASS SUPPLEMENTARY ENQUIRY

EXPERT WITNESS STATEMENT
DR DAVID BROCKWAY, CSIRO

TECHNOLOGIES FOR BROWN COAL POWER GENERATION

1 March 2007

Summary

The Latrobe Valley brown coal resource currently provides the major source of electricity for the State of Victoria. The future use of the resource for power generation and for other uses such as synthesis of transport fuels will be dependent on the development and implementation of technologies which have significantly lower greenhouse gas (carbon dioxide) emissions than current technologies. These reduced emissions will be necessary to meet community expectations, Government mandates and/or an emissions trading scheme.

The emission requirements which will apply to any particular future plant cannot be anticipated. However, technologies currently under development are capable of delivering significant emission reductions in the next 5-10 years, and near-zero emissions in a 10-15 year time frame.

A new supercritical pulverised fuel brown coal power station based on the current state-of-the-art would increase efficiency by around 20% compared to existing power stations, thus reducing carbon dioxide emissions by a corresponding amount. This technology has been commercially implemented in Germany with brown coal, and the latest black coal power stations in Queensland have comparable (but slightly less advanced) technology.

A number of advanced power generation technologies which can substantially reduce carbon dioxide emissions have been piloted and demonstrated internationally. Several of these technologies are currently being progressed at pilot and demonstration scale in Victoria for specific application to brown coals, and these technologies are likely to be commercially available early next decade.

A major focus has been on brown coal drying and dewatering technologies, given the high moisture content of Victorian brown coals. Two technologies focussed on power station application are currently at or planned for large pilot or demonstration scale. The fine grain Steam Fluidised Bed Drying Process (SFBD) process, which has been piloted in Germany, is to be demonstrated by International Power at its Hazelwood Power Station. The fine grain SFBD process has also been selected by Monash Energy for the coal pre-drying step in their coal-to-liquids project, and Monash Energy has recently purchased the existing SFBD plant (which used an earlier version of the process) at Loy Yang as a demonstration site. Successful demonstration at Hazelwood and/or Monash Energy would confirm technical viability for full scale commercial implementation by early next decade. A large pilot plant to test the scale-up of the Mechanical Thermal Expression (MTE) process is currently under construction at Loy Yang. Several other brown coal drying processes focussed on other applications have also been operated at pilot scale. The MTE process and the other drying technologies could be ready for commercial implementation by early-mid next decade.

A new supercritical power station designed for dried brown coal feed could achieve between 30 and 35% reduction in carbon dioxide emissions compared to existing stations, depending on the extent of drying. Successful demonstration of pre-drying

technologies is the principal technical pre-requisite for a commercial dried brown coal power station.

Integrated Gasification Combined Cycle (IGCC) processes are able to achieve even higher efficiencies, giving over 40% reduction in carbon dioxide emissions compared to existing power stations. HRL is planning a 400MW demonstration plant for its IDGCC version of this process, and the gasification process planned to be used by Monash Energy for its coal-to-liquids demonstration plant could also be applied to IGCC. Coal gasification for chemicals and synthetic fuels production is commercial technology, with over 150 gasifiers operating world-wide. A commercial brown coal IDGCC or IGCC process could be available by the middle of next decade following successful demonstration by HRL and/or Monash Energy.

Carbon dioxide capture and storage (CCS) can reduce power station emissions to near-zero by removal of carbon dioxide either post-combustion from existing or new pulverised fuel power stations, or pre-combustion from IGCC processes. CCS can typically reduce carbon dioxide emissions by 85%. Such a reduction would be in addition to any achieved through efficiency improvements in the power station technology. Post combustion capture (PCC) is to be demonstrated at the Hazelwood power station by the CO2CRC and International Power. CSIRO and Loy Yang Power are also planning a PCC trial facility at the Loy Yang A power station. Technologies for carbon dioxide capture are commercially proven in the oil & gas and chemicals industries, but at smaller scales than required for power station applications. The Latrobe Valley PCC programs will address technical issues specifically related to brown coal derived flue gas, and enable testing of new laboratory developments to improve PCC efficiency and costs. It is generally accepted that it will take up to ten years to prove and demonstrate large scale CCS from power stations.

In summary a range of low-emission technologies is and will be available for commercial implementation over the next two decades. These technologies have the capability to reduce carbon dioxide emissions to meet community expectations, possible Government mandates and/or an emissions trading scheme, thus ensuring that the brown coal resource can continue to be utilised even in a carbon constrained scenario.

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1. Background

1.1 Personal History, Experience and Relevance to the Panel Hearing

Dr David Brockway, BAppSc, MSc, PhD, FTSE, FAIE, FAICD
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Dr Brockway was appointed Chief, CSIRO Energy Technology, in January 2004. In this role he has responsibility for a Division of about 220 people engaged in R&D on fossil fuels, renewables, energy storage, distributed generation, energy futures modelling and the environment.

For the previous decade, he was the Chief Executive Officer of the Cooperative Research Centre for Clean Power from Lignite and its predecessor, the Cooperative Research Centre for New Technologies for Power Generation from Low-Rank Coal. He is currently a member of the Board of the Cooperative Research Centre for Coal in Sustainable Development and of the Centre for Low Emissions Electricity in Queensland.

Dr Brockway was previously a member of the Boards of the Cooperative Research Centre for Clean Power from Lignite; Generation Technology Research Pty Ltd; and the Centre for Energy and Greenhouse Technologies Pty Ltd. David was also Chairman of Laser Analysis Technologies Pty Ltd, a spin off company which is a joint venture of the CRC and another private company.

Before joining the CRC, Dr Brockway spent 13 years in the Research and Development Department of the State Electricity Commission of Victoria where he was variously Manager Scientific Investigations, Principal Materials Scientist and Head of Coal Science. In total, he has been involved in energy R&D for more than 2 decades.

1.2 Other Significant Contributor to the Statement

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Dr Jackson has over 25 years experience in energy research and development. For the period 1995 to 2006 he was employed by the Cooperative Research Centre for Clean Power from Lignite and its predecessor as Manager Research and subsequently CEO. In these roles he was directly involved in the prioritisation and management of brown coal (lignite) power generation R&D, and in the assessment of developing brown coal technologies.

1.3 Instructions

I have been engaged by the Department of Primary Industries to provide a report on the status of technologies for power generation from brown coal which may harness the value of the available coal resource in the Latrobe Valley.

2. Overview of Technologies

The future use of the Latrobe Valley brown coal resource for power generation or for other applications such as production of transport fuels and chemicals will need to be consistent with the environmental requirements prevailing at the time.

Community expectations, possible Government mandates and/or an emissions trading scheme are highly likely to require new power stations to have substantially reduced greenhouse gas (carbon dioxide) emissions compared to current plant.

There are many technologies currently under development which can reduce the greenhouse gas emissions from brown coal power generation. This statement focuses on those brown coal related technologies which are currently being actively pursued at pilot or demonstration scale in Victoria, or which are (or will be) commercially available from international power technology companies for implementation progressively over the 5-15 years.

The technologies for reducing greenhouse gas emissions broadly fall into two categories:

- those which improve the process efficiency thereby reducing the greenhouse gas emissions per unit of electricity generated, and
- those which involve the capture and storage (sequestration) of carbon dioxide from the power station.

Figure 1 illustrates the range of technology options available to reduce greenhouse gas emissions, and to achieve near-zero emissions.

The efficiency of brown coal power generation can be increased by removal of the coal moisture prior to utilisation, by improving the power generation cycle efficiency, or by a combination of these approaches.

Typical efficiencies, and corresponding levels of carbon dioxide emissions, from new brown coal power generation technologies (compared to current technology) are [Jackson, 2005]:

Technology	**Efficiency (HHV net)**	**CO2 Emissions (kg/MWh net)**
Current Stations	28	1250
New Supercritical Station (raw coal feed) (current state-of-the-art)	34	1000
New Supercritical Station (dried coal feed, 50% water removal from raw coal)	39	850
New Supercritical Station (dried coal feed, 70% water removal from raw coal)	41	820
IGCC (dry coal feed)	45	720

The new technologies with coal pre-drying can provide reductions in carbon dioxide emissions of between 30% and 42% compared to the current stations.

Figure 2 also shows the carbon dioxide emissions for a range of existing and new power generation technologies.

It should be noted that improvements in process efficiency will reduce the costs of carbon dioxide capture and storage through the reduction in gas volume per unit of electricity generated, and the consequent reduction in the size of the capture plant.

Carbon dioxide capture and storage technologies for power station application are generally characterised as:

- post-combustion capture in which carbon dioxide is separated from the flue gas of a pulverised fuel power station (see Figure 3), or
- pre-combustion capture in which carbon dioxide is separated from the fuel gas from a gasifier prior to combustion of the remaining hydrogen rich gas in a gas turbine (see Figure 4)

There are also other near-zero emission technologies under development, such as Oxyfuel combustion (see Figure 5) which involves pulverised fuel combustion in oxygen and recycled flue gas. This process produces a flue gas containing predominantly carbon dioxide and water. Following condensation of the water, the carbon dioxide stream can be compressed and stored without any other requirement for gas separation. A 30MW black coal Oxyfuel demonstration project at Callide in Queensland has recently been announced [CS Energy, 2007], and Vattenfall has commenced construction of a 30MW brown coal Oxyfuel demonstration plant in Germany [Vattenfall, 2006].

Technologies which involve carbon dioxide capture and storage typically capture 85% of the carbon dioxide from the power station [IPCC, 2005]. Hence the combination of a new high efficiency technology with carbon dioxide capture and storage can provide even lower emissions than carbon dioxide capture and storage retrofitted to an existing power station. The IPCC study also indicated that within the accuracy of the study, most of the likely carbon dioxide capture technologies currently have similar costs [IPCC, 2005].

The following sections provide details on the new brown coal technologies and their status of development.

3. Coal Drying/Dewatering

3.1 Water in Victorian Brown Coal and its Removal

The high moisture content of Victorian brown coals is a major issue in their commercial utilisation [Allardice, 1991]. The moisture contents of the Latrobe Valley brown coals are typically in the range 60-66% (wet basis) or 150-200% (dry basis). In conventional (existing) brown coal fired pulverised fuel boiler plants, the high coal moisture content leads to low thermal efficiency, high carbon dioxide emissions and high capital costs of plant.

The removal of the coal moisture by energy efficient means prior to utilisation will improve thermal efficiency and consequently reduce carbon dioxide emissions.

A large number of technologies for removal of water from brown coal have been proposed since the resource was first discovered and considered for exploitation [Allardice, 1991; Allardice at al, 2004]. These technologies broadly fall into two categories – evaporative drying processes in which water is removed as water vapour; and non-evaporative dewatering processes in which water is removed as a liquid. The dewatering processes generally require less net energy input since the latent heat of vaporisation is avoided, and have the advantage that soluble inorganic constituents in the coal (which contribute to boiler fouling) are removed in proportion to the extent of water removal, thus improving coal quality.

Some of these technologies have been developed to small commercial scale for specific applications, but none of the technologies has as yet been developed to the necessary commercial scale for drying or dewatering the feed to a major Latrobe Valley power station.

Several technologies are currently at or progressing to pilot or demonstration scale, and will be potentially available for commercial application within the next five years.

3.2 Steam Fluidised Bed Drying (SFBD)

The drying of brown coal using steam in a fluidised bed was invented by Professor Potter of Monash University in the 1970s [Potter and Keogh, 1979; Potter at al, 1984]. A version of the process was further developed in the former East Germany. Lurgi and Rheinbraun subsequently designed a commercial demonstration scale plant, and two plants (150,000 tonne per year dried coal nominal capacity) were constructed at Loy Yang in the Latrobe Valley and at Rheinbraun's Wachtberg briquette factory at Frechen in (West) Germany [Allardice et al 2004].

The SFBD process removes moisture from raw coal by evaporation in a bed that is fluidised with superheated steam at normal pressure. The principal heating for the bed is provided by closely spaced heat exchanger tubes with steam at a higher temperature than that in the bed. Because the heat transfer coefficient is higher in a fluidised bed than in conventional tubular dryers, the process allows for relatively high capacity dryers to be built [Schmalfeld and McKenzie, 1993; Schmalfeld and

Twigger, 1996]. The energy in the product steam can be recovered or used in the process, thus reducing the net energy input. The Loy Yang plant dries coal from an initial moisture content of about 62% down to around 12% (wet basis).

The Loy Yang plant operated from 1992 to 2003 to produce dried coal as start-up and auxiliary fuel for the Loy Yang B power station, but in 2003 that station was converted from dried coal to natural gas start-up and auxiliary fuel. The plant has been closed since 2003, but was purchased by Monash Energy in 2006 (see below) [Monash Energy, 2006a].

The Wachtberg plant operated from 1993 to 1999, producing dried coal for a variety of uses.

In 2000, RWE (the parent company of Rheinbraun) designed and constructed a 66 tonne per hour (dried coal) demonstration plant at RWE's Niederaussem power station, but this plant was closed in 2002 without ever having been operated at its design conditions [Ewers et al, 2003].

(Note that RWE calls their version of the process WTA, which is an abbreviation of the German for "fluidised bed drying with internal waste heat utilisation").

RWE (through subsidiary RE Engineering) has developed an improved version of the SFBD process, incorporating the use of fine grain particles (<2mm). The use of fine particles improves the heat transfer in the fluidised bed, and results in a significant reduction in plant capital cost [Ewers et al, 2003].

RWE has operated a fine grain SFBD pilot plant (17 tonnes per hour dried coal) at Frechen since 2000, and is planning to scale up to demonstration scale in 2007 with the aim of commercial implementation in 2011 in the next generation of supercritical steam cycle brown coal power stations (BOA Plus) [Ewers et al, 2003].

Monash Energy has selected the fine grain SFBD process as its preferred technology for drying the feed coal to the gasification process step in its proposed coal-to-liquids project [Monash Energy, 2007]. RWE undertook drying tests on a Victorian brown coal in the Frechen plant for Monash Energy in April 2005. At the conclusion of the tests, 25 tonnes of dried coal was tested for its gasification performance.

International Power – Hazelwood has recently announced a project to demonstrate the use of the RWE fine grain SFBD process to dry the coal feed to one of its 200MW units at the Hazelwood Power Station [International Power, 2006]. This project is being co-funded by International Power, the Commonwealth Government (through the Low Emission Technology Demonstration Fund) and the Victorian Government (through the Energy Technology Innovation Strategy Large Scale Demonstration Program). The conversion of the unit to dry coal feed will reduce carbon dioxide emissions from that unit by 30% [International Power, 2006].

Successful demonstration at Hazelwood and/or Monash Energy would confirm technical viability of the SFBD process for full scale brown coal commercial implementation by early next decade.

3.3 Mechanical Thermal Expression (MTE)

Press dewatering of Victorian brown coals at ambient conditions was initially investigated in the 1980s [Burton and Banks, 1985; Burton and Banks, 1989]. Substantial reductions in moisture content were achieved (up to 80%), but very high pressures and long residence times were required to achieve such moisture reductions.

More recently, workers at the University of Dortmund developed a brown coal press dewatering process at elevated temperatures (150-200ºC) [Strauss, 1996; Strauss et al, 1996]. The use of elevated temperatures provided some thermal dewatering, and enabled reduced compression pressures and residence times due to softening of the coal. This process was called Mechanisch/Thermischen Entwässerung or MTE – German for Mechanical/Thermal Dewatering. The relatively low temperatures avoided decarboxylation of the coal and substantial organic loss into the expressed water.

The CRC for Clean Power from Lignite was also working on press dewatering of coal slurries at that time, and subsequently developed a variant of the Dortmund process which was termed Mechanical Thermal Expression (MTE). Studies by the CRC indicated that MTE was a lower cost process and provided greater overall efficiency improvements than SFBD and Hydrothermal Dewatering for retrofit to existing boilers, for new dry-coal boilers, and for IGCC feed pre-drying [McIntosh, 2001].

The CRC MTE process involves preheating a coal slurry formed with minimal added water, mechanical compression of the heated slurry to expel water, and removal of the compressed coal from the pressure cell. The process has been tested with several Latrobe Valley coals, and typically 70% of the feed coal moisture can be removed, giving a product moisture content of between 25 and 30% (wet basis). The CRC successfully operated a one tonne per hour pilot plant, following development of the process at laboratory scale [McIntosh; 2003; McIntosh and Huynh, 2005].

A 15 tonne per hour MTE pilot plant is currently under construction at the Loy Yang Power site in the Latrobe Valley. This large pilot plant project is being co-funded by the Latrobe Valley power generation companies, the Commonwealth Government (through the Australian Greenhouse Office) and the Victorian Government. This plant is expected to be operational by mid-2007 and will have a 6-9 month test program.

Successful testing of the MTE process at the 15 tonne per hour scale is likely to be followed by demonstration scale testing at around 100 tonne per hour. Based on this development pathway, the technical viability of the MTE process for full scale brown coal commercial implementation could be confirmed by early-mid next decade.

3.4 Other Drying and Dewatering Technologies

Several other brown coal drying and dewatering technologies are also currently under development in Australia.

Exergen is developing a variant of the Hydrothermal Dewatering (HTD) Process [Exergen, 2006]. HTD involves heating a coal slurry to around 300ºC at sufficient pressure to prevent evaporation of the water. The thermal treatment results in expression of water from the coal due to a combination of factors [Allardice, 1991; Allardice et al, 2004]. The SECV investigated a version of the HTD process [Allardice et al, 1995], but subsequently ceased development of the process to concentrate on the IDGCC process (see below).

The Exergen has successfully operated a 4 tonnes per hour continuous pilot plant, and plans, subject to funding assistance from Government, to construct a 200 tonnes per hour demonstration plant. Alcoa Australia and Thiess are supporting this project, and the Alcoa Anglesea Power Station is a potential site for the demonstration plant [Exergen, 2006].

Two other groups are developing coal drying processes, targeted principally at dried coal products rather than power station use.

Asia Pacific Coal and Steel Pty Ltd (acquired in 2006 by Environmental Solutions International Ltd, which subsequently changed its name to Environmental Clean Technologies Ltd) is developing the Coldry Process [ECT, 2006]. This process was developed by Maddingley Technology Pty Ltd based on earlier research at the University of Melbourne funded by CRA [Johns et al, 1986; Johns et al 1989]. Maddingley Technology has operated a 5 tonnes per hour pilot plant at the Maddingley brown coal mine near Bacchus Marsh since 2004. The Coldry Process involves shearing the coal to liberate some of the coal moisture to form a paste, extrusion of the paste to form pellets, and warm air drying of the pellets to form a hard pellet product. A variant of the process (termed the Matmor Process) involves mixing iron ore fines with the coal prior to extrusion to form 50/50 pellets of iron ore and dried coal. These pellets would form the feed for a direct ironmaking process.

Latrobe Lignite Developments (LLD) Pty Ltd, and its associated company Pacific Edge Holdings (PEH) Pty Ltd, are developing a drying process which is also based on the research at the University of Melbourne. In the LLD process, the coal is sheared to form a paste and then extruded into pellets which are subsequently heated in a kiln to produce evaporated water, pyrolysis gas and a char product. A variant of the process produces dried coal pellets or briquettes rather than char. PEH has operated a three tonnes per hour (product briquettes) pilot plant at Coimadai near Bacchus Marsh. A larger pilot plant to produce 50 tonnes per hour of briquettes was announced in 2004 [Brumby, 2004], but this plant has not yet been constructed.

The development timetables for the Exergen, Coldry and LLD/PEH processes are somewhat uncertain given that none of the proposed scale-up projects is currently underway. However, if progressed as planned, these technologies could be technically proven for commercial implementation by early-mid next decade.

4. Pulverised Fuel Boilers

4.1 Current Latrobe Valley Power Stations

The existing Latrobe Valley power stations have boilers with sub-critical steam conditions. The power stations have varying efficiencies, reflecting the state-of-the-art technology at their time of construction.

The efficiency of power generation from the conventional pulverised fuel-fired boiler power stations is significantly influenced by the high coal moisture content of the coal. The efficiency obtained from the modern boiler plant at Loy Yang A and B power stations is about 28% on a higher heating value basis (HHV) for a coal moisture content of 62%. The comparable efficiency for conventional boiler plant fuelled with high-rank (black) coals is about 37%.

4.2 Supercritical and Ultrasupercritical Power Stations

The current state-of-the-art brown coal fired power stations employ supercritical steam conditions. The highest efficiency power station operating on brown coal feed is the 1000MW Neideraussem K station commissioned in 2002 in Germany. This station has an efficiency of 45.2% on a lower heating value basis (LHV) (as generally used in Europe) or 37.7% on a higher heating value basis (HHV) for a coal moisture content of 53% [Heitmuller et al, 1999; Ewers et al, 2003]. If a Neideraussem K design plant was operated with higher moisture content Loy Yang brown coal feed, the efficiency would be reduced to 34.5% (HHV) [McIntosh, 2003b].

The increase in efficiency over the 15-20 year time period between the design of the Loy Yang and Neideraussem power stations is due to a combination of factors including:

- higher pressure and temperature steam conditions (to supercritical conditions)
- improved flue gas heat recovery
- reduced in-station power consumption
- reduced condenser pressure
- improved steam turbine efficiency
- process optimisation

Supercritical power stations are commercially available from a number of major power technology companies. The Millmerran power station in Queensland, commissioned in 2003, has two supercritical 440MW black coal boilers. The Kogan Creek power station also in Queensland, to be commissioned in late 2007, has a single supercritical 750MW black coal boiler.

The efficiencies of new pulverised fuel power stations will continue to increase as new steam tube materials currently under development are commercialised to permit higher temperature and pressure steam conditions (to ultrasupercritical steam conditions).

4.3 Post Combustion Capture from Pulverised Fuel Power Stations

Post combustion capture is the most flexible of the carbon dioxide capture and storage technologies, and has other important attributes:

- It can be retrofitted to existing plants, and is the most practical means of substantially reducing greenhouse gas intensity.
- It can be integrated into new advanced supercritical and ultra-supercritical pulverised fuel plants to achieve a range of greenhouse gas intensity reductions down to essentially zero emissions (less than 75 kg CO_2/MWh).
- Aadvanced supercritical pulverised fuel plant with PCC plant are expected to match the greenhouse gas intensity of, and to be cost competitive with, the competing CCS options of IGCC and oxy-combustion. Part of the cost effectiveness of PCC is that most of the energy for the process is provided by low temperature heat (around 120°C) rather than by electricity. The smaller parasitic electrical demand for PCC reduces the capital cost multiplier, especially compared to oxy-pf combustion.
- It has higher operational flexibility (partial retrofit, variable zero to full capture operation) and can match market conditions for both existing and new pf plant. For instance, at time of high power prices, PCC can be turned off and maximum power delivered to the market.
- It offers a lower technology risk compared to competing technologies. This is further enhanced by the ability for staged implementation, which is not possible with competing all-or-nothing technologies.
- It has a significant development potential, through process improvements and new sorbents, and the rate of these developments will be enhanced by the high flexibility and adaptability of the process.

International Power has recently announced a project, in conjunction with the CO2CRC, to demonstrate carbon dioxide capture at the Hazelwood power station [International Power, 2006]. International Power, the CO2CRC, CSIRO and Loy Yang Power have also submitted an application to the Victorian Government for funding of a coordinated R&D program on PCC from brown coal power station flue gases. This joint R&D program will include a PCC trial at the Loy Yang A power station utilising a CSIRO mobile test facility, in addition to R&D on the Hazelwood plant.

The Latrobe Valley PCC projects will address technical issues specifically related to brown coal derived flue gas, and enable testing of new laboratory developments to improve PCC efficiency and costs.

Technologies for carbon dioxide capture are commercially proven in the oil & gas and chemicals industries, but at smaller scales than required for power station applications. The technical challenges for large scale power station application include improvements in energy efficiency and in tolerance of sorption solvents to brown flue gas impurities.

The status of CCS technologies is addressed in the Expert Witness Statement by Dr Peter Cook. However, it is generally accepted that it will take up to ten years to prove and demonstrate large scale CCS from power stations.

5. Advanced Power Generation Processes

5.1 Overview

A number of advanced technologies have been developed worldwide to improve thermal efficiency of coal-fired power production and reduce the emission levels of CO_2, NO_x, and SO_x in a cost competitive manner. These include Circulating Fluidised Bed Combustion (CFBC), Pressurised Fluidised Bed Combustion (PFBC), Integrated Gasification Combined Cycle (IGCC) and Advanced Pressurised Fluidised Bed Combustion (APFBC) technologies. Most developments of these advanced technologies are focussed on the use of high-rank coals.

The CRC for New Technologies for Power Generation from Low-rank Coal undertook a comprehensive series of process evaluations for the utilisation of low-rank coals in advanced power technologies [Bhattacharya and McIntosh, 1997; McIntosh, 1997]. The evaluations considered the requirement to incorporate a coal drying process into the technologies and other issues specific to the utilisation of low-rank coals for power generation. A number of coal drying processes were investigated and integrated into the power generation cycles. The impact of the properties of low-rank coals such as coal reactivity, alkalinity of the ash, alkali and dust removal from hot gas and the difficulty of handling raw (soft) low-rank coal were also considered.

Assuming 100% carbon conversion, the process evaluations showed that efficiencies as high as 42% (HHV) can be achieved from technologies utilising coal gasification. However, it is known that carbon conversion is not complete in the High Temperature Winkler (HTW) fluidised bed type of gasifier generally proposed for low-rank coals. Comprehensive research undertaken in Germany by a consortium led by RWE developed a technology based on HTW that is expected to achieve about 91 percent carbon conversion in the gasifier. As a consequence RWE proposed a cycle in which the char is burnt in a separate boiler at atmospheric pressure.

In the likely real case where the char yield is 9 percent in the IGCC systems and (say) 22 percent in the two hybrid systems (which do not aim to achieve complete gasification of coal), the efficiencies (with atmospheric char combustion coupled to IGCC) determined in the study were:

CFBC (32.1%) (SFBD) <PFBC (38.4%) (SFBD) <PG/CFBC (38.7%) (SFBD) <(IGCC) (39.5%) (Hot gas drying) <IGCC (40.5%) (SFBD) <APFBC (44.4%) (SFBD)

Since that earlier study by the CRC, the APFBC Process, though providing high efficiencies, has not been further developed largely due to the complexity of the process and the extent of integration of the pressurised gasification and combustion stages. International developments of advanced power generation processes, particularly in the United States and Japan, have subsequently focussed on IGCC processes.

The CRC for Clean Power from Lignite subsequently undertook an evaluation of pulverised fuel and IGCC technologies to assess their relative cost and performance

[McIntosh, 2003a; McIntosh, 2003b]. The efficiencies of the brown coal processes assessed in that study were:

Supercritical pulverised fuel boiler plant (raw coal)	33.6%
Supercritical pulverised fuel boiler plant (MTE coal)	39.1%
Air blown IGCC (transport reactor gasifier) (MTE coal)	46.0%

Coal gasification for chemicals and synthetic fuels production is commercial technology, with over 150 gasifiers operating world-wide. Several demonstration scale IGCC plants have been constructed and operated in the USA, the Netherlands and Spain. All of these plants have been designed for, and operated with, black coal feed. However, much of the know-how gained in operating these large scale plants will also be relevant to brown coal IGCC.

Two brown coal gasification projects are currently being pursued in Victoria, and these are described below.

5.2 IDGCC

A specific process variation of the IGCC technology for high moisture brown coals, Integrated Drying Gasification Combined Cycle (IDGCC), was initially developed by the SECV, and has been further developed by HRL Limited [Pleasance and Wilson, 1993; Pleasance and Johnson, 1996].

The IDGCC process incorporates an entrained flow hot gas drying process, using gasifier exit gas to pre-dry the coal feed. The process was piloted at 250 kg per hour scale, and subsequently scaled-up to 10 tonnes per hour scale.

HRL has recently announced the signing of a Memorandum of Understanding (MOU) with Harbin Power Equipment Group Corporation (China) to develop a 400 MW demonstration power station in Victoria's Latrobe Valley using the IDGCC technology and to explore future development of other power plants globally [HRL, 2006].

In the lead-up to the November 2006 Victorian Election, the Labour Party committed to provide $50 million in support of HRL’s proposed $750 million 400 MW demonstration IDGCC power station (subject to Commonwealth Government funding) [ALP 2006].

A commercial brown coal IDGCC process could be available by the middle of next decade following successful demonstration by HRL.

5.3 Monash Energy

Monash Energy (owned by Anglo American) is developing a coal-to-liquids project which involves brown coal pre-drying using the RWE fine grain SFBD process, entrained flow gasification to produce synthesis gas (a mixture of predominantly hydrogen and carbon monoxide), followed by Fischer-Tropsch synthesis to produce a diesel transport fuel product [Monash Energy, 2007]. Carbon dioxide capture and storage is a key component of the project.

Recently Anglo American and Shell announced a Joint Development Agreement to jointly advance the Monash Energy coal to liquids project [Monash Energy, 2006b].

The Shell entrained-flow gasification process proposed for the Monash Energy project could also be applied to IGCC. The successful demonstration of the Shell gasification process in the planned demonstration coal-to-liquids plant could also lead to that gasification process being proven for brown coal IGCC application by the middle of next decade.

6. Declaration

I declare that I have made all the enquiries that I believe are desirable and appropriate and that no matters of significance which I regard as relevant have to my knowledge been withheld from the panel.

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8. Figures

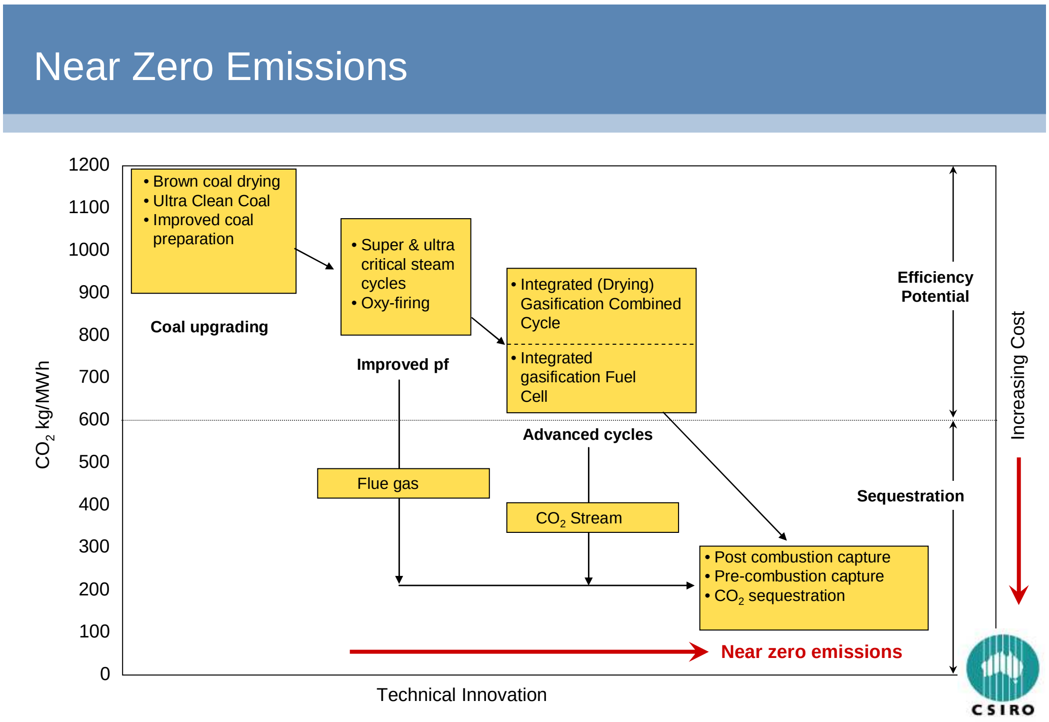

Figure 1

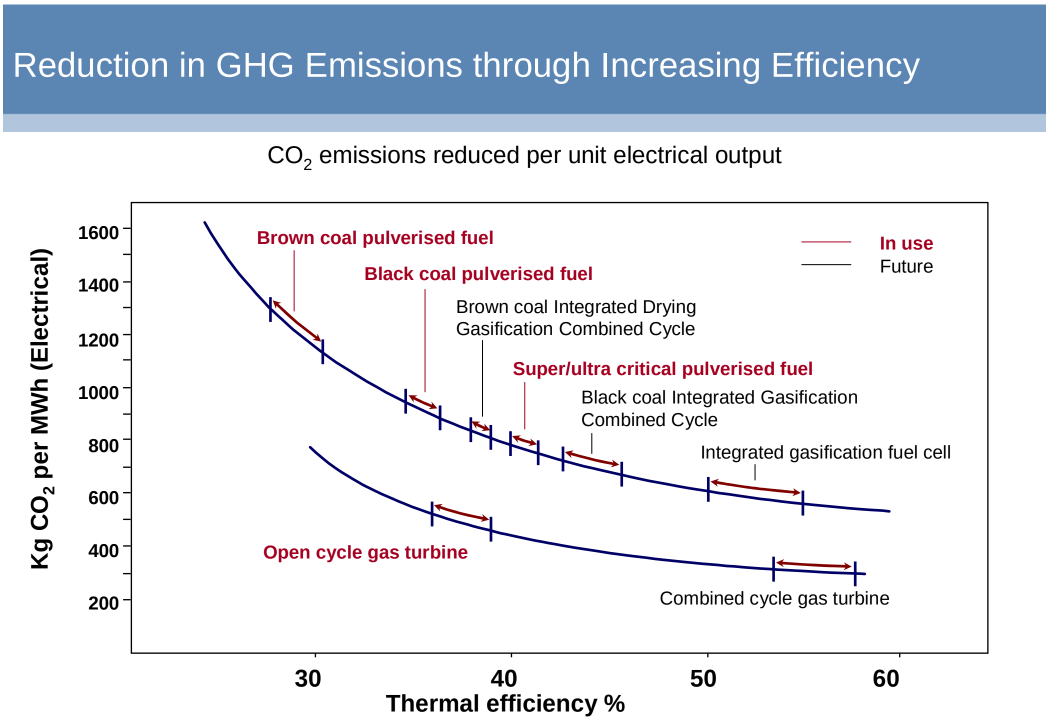

Figure 2

Pf power plant with post combustion capture technology

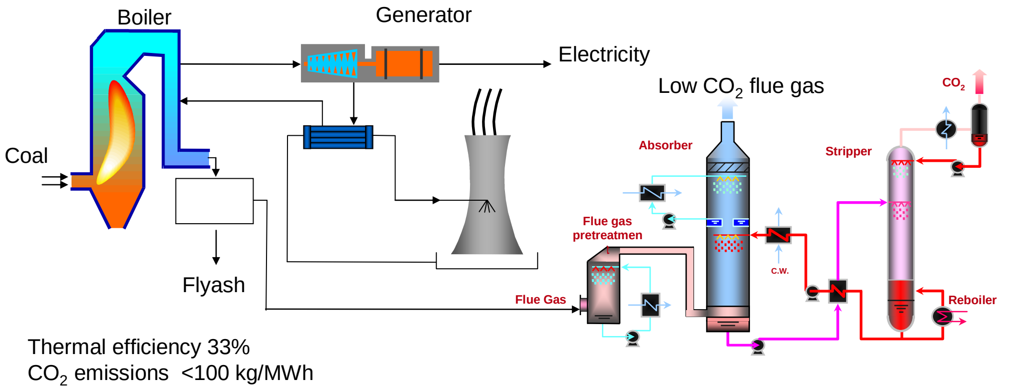

Figure 3

Integrated Gasification Combined Cycle with Carbon Capture

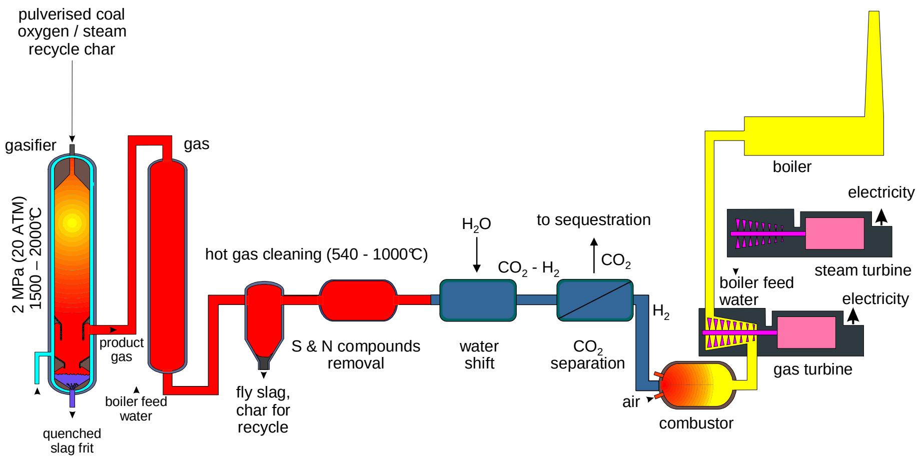

Figure 4

OxyFuel pf Boiler

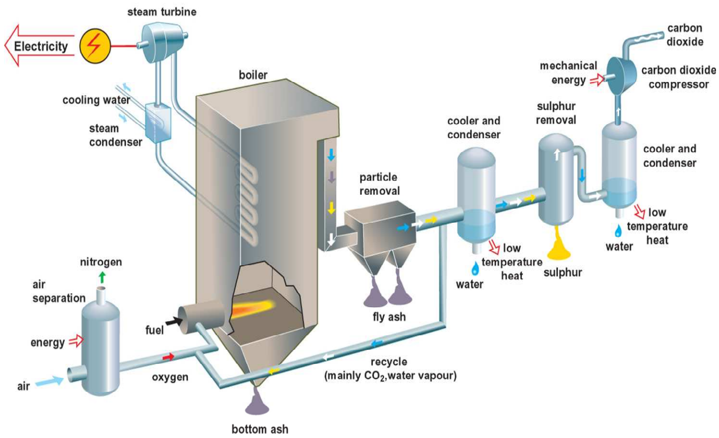

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Figure 5