VCAT Review of EPA Works Approval Application by Dual Gas Pty Ltd
Expert opinion prepared by Hugh Outhred

Witness information

Name and Address

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Qualifications

Bachelor of Science (Mathematics & Physics)
Bachelor of Engineering in Electrical Engineering (Hons 1)
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Affiliations

Fellow, Australian Institute of Energy
Member, Institute of Electrical and Electronic Engineers

Experience

Hugh Outhred is a Director of Ipen Pty Ltd, a company established in 1998 to provide independent perspectives on energy. He is also a Professorial Visiting Fellow at the University of New South Wales (UNSW), an Adjunct Professor at Murdoch University and *Guru Besar Luar Biasa* at STTNAS Jogjakarta, Indonesia. After a 35-year career at UNSW, Hugh Outhred retired in 2007 as Presiding Director, Centre for Energy and Environmental Markets and Head, Electrical Energy Research Group, School of Electrical Engineering and Telecommunications. During his career, Hugh has been a Fulbright Senior Fellow at the University of California Berkeley, a Board Member of the Australian Cooperative Research Centre for Renewable Energy, an Associate Director of UNSW's Centre for Photovoltaic Devices and Systems, a Member of CSIRO's Energy Flagship Advisory Committee, a Member of the National Electricity Tribunal and a Member of the New South Wales Licence Compliance Advisory Board. He has also held visiting positions at Massachusetts Institute of Technology and Lawrence Berkeley National Laboratory in the USA, the University of Liverpool in the UK, the Universidad Pontificia Comillas in Spain and Roskilde University Centre in Denmark. He was a Lead Author for the IPCC Special Report on Renewable Energy and Climate Change Mitigation (2011). He has taught nearly 100 short courses on electricity industry technology, competition, policy, regulation and sustainability since 1988.

Expertise to provide report

Hugh Outhred has contributed to the theory of electricity industry competition since 1979 and to its practical implementation in Australia since the 1980's. In 1985 and 1986, he was seconded to the Energy Authority of New South Wales as an advisor on electricity industry development and sustainability and to lead a newly established energy-forecasting branch. In 1995 and 1996 he led a project for the National Grid Management Council to undertake electricity-trading experiments to trial the proposed National Electricity Market trading rules prior to their formal implementation. In 1997, he was appointed as an inaugural member of the NSW Licence Compliance Advisory Board, a position he held until the Board was replaced as part of revised industry governance arrangements in 2001, and in 1998 he was appointed as an inaugural member of the Australian National Electricity Tribunal, a position he held until the Tribunal was replaced as part of revised industry governance arrangements in 2006. In From 2005 to 2009, Hugh led a UNSW research project for the Australian Greenhouse Office on facilitating the uptake of wind energy in the Australian electricity industry and in 2010 he lead a project for the Australian Electricity Market Operator to develop a prototype tool to predict large, rapid changes in the aggregated power output of wind farms in the National Electricity Market.

Instructions that define the scope of this report (EDO Victoria)

The State Environmental Protection Policy (Air Quality Management) (SEPP (AQM)) and the Protocol [for Environmental Management – Greenhouse Gas Emissions and Energy Efficiency In Industry] are the main legal documents that govern emissions of greenhouse gases by new facilities in Victoria and are the central documents that will guide VCAT's decision.

One of the main requirements in the SEPP (AQM) for new sources of greenhouse gas emissions is that they apply 'best practice' to the management of emissions. 'Best practice' is defined and discussed in more detail in clauses 18 and 19 of the SEPP (AQM) and section 1.4.2 of the Protocol.

We seek your opinion as to whether the Dual Gas proposal can be considered 'best practice'.

In addition, we ask that you examine and review the expert material which has been (or is to be) provided by EPA and Dual Gas and comment upon, where you consider necessary or appropriate, the methodology and or conclusions reached by any of the experts in their assessment of the proposal in the context of whether or not the proposal can be properly described as "best practice".

Facts, matters and assumptions on which this report is based

Discussed where relevant in the report

Documents and other material instructed to be considered

Described in Instructions above and/or referenced in the report

Questions falling outside the scope of the expert's expertise

Not relevant

Declaration

I have read the VCAT Practice Note and agree to abide by it. I have made all the inquiries that I believe are desirable and appropriate and no matters of significance that I regard as relevant have to my knowledge been withheld from the Tribunal.

Hugh Outhred, 18/10/2011

Part 1. Opinion on whether the Dual Gas project can be considered ‘best practice’

Summary of the opinion

In my opinion, the Dual Gas Demonstration Project (DGDP) as proposed in the Works Approval Application should not be considered ‘best practice’ for the following reasons:

(a) To be classified as ‘best practice’ a technology should already have been deployed and shown to have desirable qualities compared to alternative technologies in the relevant context.

(b) The relevant context for the DGDP is the National Electricity Market (NEM) with an additional objective of reducing climate change emissions.

(c) With a Greenhouse Emission Intensity (GEI) of about 0.8 tCO_2-e/MWh in dual-fuel mode, the DGDP would have a higher GEI than either gas-combined cycle or renewable energy generation – proven generation technologies in the NEM that have been regularly chosen by investors as commercially viable projects.

(d) In addition, prudential and efficient energy use is a proven option in the NEM that completely avoids climate change emissions.

(e) The DGDP would also have a higher GEI than either ultra-supercritical black coal or IGCC black coal, technologies that are now in the demonstration phase.

(f) Even within the narrow context of IDGCC, the DGDP as originally proposed should not be regarded as best practice. The approved version is an improvement in the sense that it is more closely focused on the use of gasified brown coal.

(g) Modifying the DGDP to use a higher-efficiency class F combustion turbine design would lower its GEI and should be fully explored.

(h) Adding carbon capture, transport and storage (CCS) to the DGDP would reduce its GEI but may not be a practical option yet. Moreover, an integrated CCS project would have environmental risks associated with each stage in the CCS process and would thus rank lower than avoiding emissions in the SEPP (AQM) wastes hierarchy.

Future improvements in conversion efficiency and implementing carbon capture and storage could change the picture. In accordance with the principles of eco-efficiency enunciated by the World Business Council on Sustainable Development (WBCSD) and relevant aspects of the SEPP (AQM), it is my opinion that further consideration of approval of the Dual Gas project should be deferred until (a) it can use more efficient CCGT technologies and (b) it can be designed and, if approved, implemented as part of a fully integrated CO_2 capture, transport and storage project. The project should be re-considered for approval in the NEM context that exists at that time.

The Dual Gas Demonstration Project

The Dual Gas EPA Works Approval Application defines the proposed project as follows:

The Dual Gas Demonstration Project (DGDP) comprises the development of a demonstration power station using Integrated Drying and Gasification Combined Cycle (IDGCC) technology, which will generate approximately 600 MW of power for sale in the National Electricity Market (NEM). The primary fuel for power generation will be synthetic gas (syngas) generated from brown coal and natural gas is expected to be used as a start-up fuel, as well as a supplementary fuel (Dual Gas EPA Works Approval Application, 1 September 2010, p 13).

Interpretation of the term 'best practice' in the context of the DGDP

'Best practice' is a term that is used by many professions and may have a particular interpretation in each. For the purpose of this report, we need to consider the policy intent, the nature of the project and the industry context in which the project would operate.

The State Environmental Protection Policy (Air Quality Management) (SEPP (AQM)) defines 'best practice' for projects subject to the SEPP (AQM) as follows:

> *'best practice' means the best combination of eco-efficient techniques, methods, processes or technology used in an industry sector or activity that demonstrably minimises the environmental impact of a generator of emissions in that industry sector or activity*

Two definitions of 'best practice' relevant to general industry practice are:

- *A best practice is a method or technique that has consistently shown results superior to those achieved with other means, and that is used as a benchmark. In addition, a "best" practice can evolve to become better as improvements are discovered*[1]
- *A "Best Practice" is a practice with redeeming qualities and attributes that has been proven through implementation and would be beneficial for others to use.*[2]

The above definitions all require a technology to have already been deployed and demonstrated/shown/proven to have desirable qualities compared to alternative technologies in the relevant context before it can be deemed 'best practice'. The concept of 'eco-efficiency' is discussed later in this report and in Appendix A.

To interpret 'best practice' in the specific context of the DGDP, we need to consider the nature of the project:

- *development of a demonstration power station using Integrated Drying and Gasification Combined Cycle (IDGCC) technology, which will generate approximately 600 MW of power for sale in the National Electricity Market (NEM) (Dual Gas EPA Works Approval Application, 1 September 2010, p 13)*
- *The proposed demonstration power station of the DGDP is planned to be commissioned to supply full generation capacity (approximately 600MW) to the grid by 2013, and thus is expected to assist in meeting Victoria's projected growing electricity demand (Dual Gas EPA Works Approval Application, 1 September 2010, p 14)*
- *Dual Gas believes it can assist in reducing Australia's carbon pollution directly in this Dual Gas Demonstration Project and indirectly by assisting HRL to commercialise and further develop its IDGCC technology (Dual Gas EPA Works Approval Application, 1 September 2010, p 14)*

From the above, we can conclude that the objective of the project is to demonstrate a new technology rather than deploy a proven one. We can also conclude that the context for consideration of best practice is:

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[1] http://en.wikipedia.org/wiki/Best_practice, accessed 3/10/11, quoting Bogan, C.E. and English, M.J., 1994: *Benchmarking for best practices: winning through innovative adaptation.* McGraw-Hill, New York.

[2] Best Practices Brochure, US Department of Energy, www.efcog.org/bp/index.htm. Accessed 3/10/11

(a) The National Electricity Market (NEM) as the “industry sector” and electricity generation as the specific ‘activity’

(b) Reduction of Australia’s climate change emissions as the primary environmental objective within a broader ‘eco-efficiency’ objective.

The National Electricity (South Australia) Act 1996 and the National Electricity Rules define the National Electricity Market (NEM) and its modus operandi. From those sources, we can deduce that the NEM consists of the wholesale market operated by the Australian National Energy Market Operator (AEMO), the interconnected transmission and distribution systems of the participating jurisdictions[3] and all electricity generating and consuming equipment connected to those systems (see Appendix B for a more formal discussion).

Key aspects of industry ‘best practice’ in the National Electricity Market (NEM) are outlined in the National Electricity (South Australia) Act 1996 and the National Electricity Rules. They include (see Appendix B for further discussion):

- Promotion of efficient investment in, and operation and use of, electricity services with respect to the long-term interests of consumers of electricity, with respect to price, quality, safety, reliability and security of supply of electricity and the reliability, safety and security of the national electricity system
- Minimisation of distinctions between market participants (generators, customers, network service providers, noting that each of these categories have different obligations under the NER)
- Minimisation of special treatment with respect to different technologies used by market participants (technology neutrality) with, for example, no use of the terms ‘base load’, ‘intermediate’ or ‘peak’ generation or reference to primary energy type except for the category of “intermittent generation”.

Thus the ‘best practice’ intent of the NEM as an electricity industry is to select in an unbiased manner (by competitive processes where possible and efficient regulation where not) the set of electricity industry resources, from among all of the eligible resources in the participating jurisdictions, that best meet the specified price, quality, safety, reliability and security objectives. The set of eligible resources includes but is not limited to technologies for electricity generation and selection takes place for both operation and investment.

While the intent of the NER is to minimise distinctions between different generation technologies, distinctions are made between market and non-market generators, and between scheduled, non-scheduled and semi-scheduled generators.

The distinctions between market and non-market and between scheduled and non-scheduled are primarily about size on the grounds that the cost to small generators of complying with some aspects of the market rules would outweigh the social benefits from requiring them to do so.

The ‘semi-scheduled’ category was introduced to accommodate generators that use non-storable, variable and uncertain primary energy fluxes such as wind or solar energy. Semi-

[3] The jurisdictions participating in the NEM are Queensland, New South Wales, the ACT, Victoria, South Australia, Tasmania and the Commonwealth of Australia (through its role in the Snowy Mountains Scheme).

scheduled generators are treated like non-scheduled generators unless the central dispatch process in the NEM requires their output to be kept lower than their forecast unconstrained output, in which case they are treated like scheduled generation.

The DGDP generating unit(s) would be classified as scheduled market generating units. They would compete with all other similarly classified generating units and with semi-scheduled market generating units under the conditions described in the paragraph above.

Two annual reports produced by the Australian Electricity Market Operator (AEMO) illuminate trends in the set of 'best practice' electricity generation technologies deployed by investment decisions in the NEM[4]:

- *Electricity Statement of Opportunities (ESOO)*
- *National Transmission Development Plan (NTNDP)*

Figure 2-3 from the 2011 ESOO (below) compares installed generating capacities in the NEM by fuel type for the year 2000 and the year 2011, showing the effects of investment and retirements over most of the period that the NEM has been in place. The increases in capacity may be summarised as follows:

Technology	Year 2000 MW	Year 2011 MW	Increase in MW (%)
Black coal	17,908	20,480	2572 (14%)
Brown coal	7,165	7,375	210 (3%)
Natural gas & Gas other	3,582	10,029	6,447 (180%)
Hydro	6799	7669	870 (13%)
Liquid fuel	831	784	-47 (-6%)
Biomass	187	367	187 (96%)
Wind	0	1779	1779 (n/a)
Total installed capacity	36,472	48,483	

Thus in the last decade, gas-based generation has had the largest growth in MW terms while wind has had the largest growth in % terms as, according to the 2011 ESOO, it started from a zero base in 2000. Gas-based generation, wind generation and the other growing technologies in the above table can be regarded as proven technologies in the NEM. There have been no new brown coal units installed and the brown coal category is only growing because of refurbishment upgrades to generating units already operating in 2000. Its share of energy generated in the NEM is declining and, according to Table A3-9 in the 2011 ESOO, the actual energy generated by brown coal power stations in Victoria declined successively in the last three financial years (47.0 TWh in 2008-9, 46.3 TWh in 2009-10 and 46.0 TWh 2010-11).

[4] Documents produced by AEMO are available for download at www.aemo.com.au.

Figure 2-3 — Installed capacities by fuel source

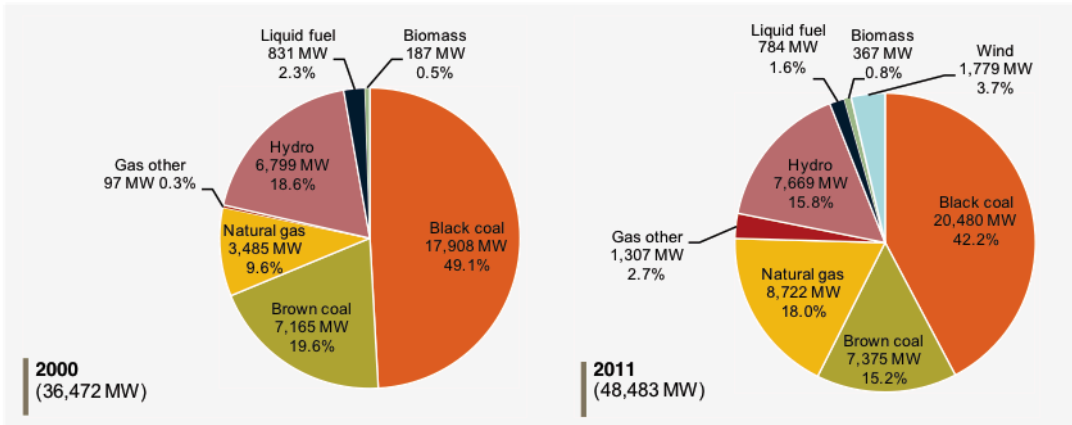


Figure 2-3, 2011 Electricity Statement of Opportunities, AEMO

Figure 8-1 from the 2011 ESOO (below) compares installed generating capacities in the NEM by fuel type for 2011 with committed and advanced construction projects in 2011. Wind and natural gas dominate the committed and advanced construction projects. In AEMO parlance, "committed and advanced" generation projects are likely to be successfully commissioned[5].

Figure 8-1 — Comparison of existing (installed) generation, and committed projects and advanced proposals by fuel source

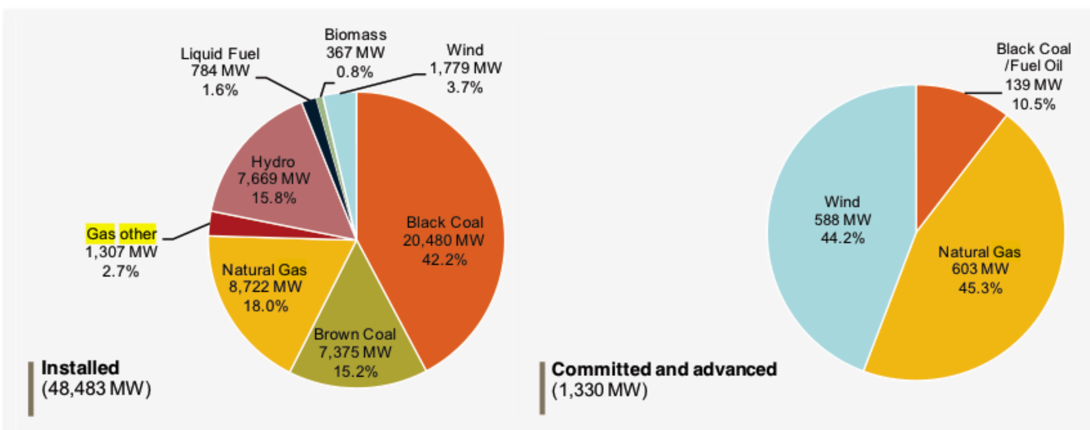


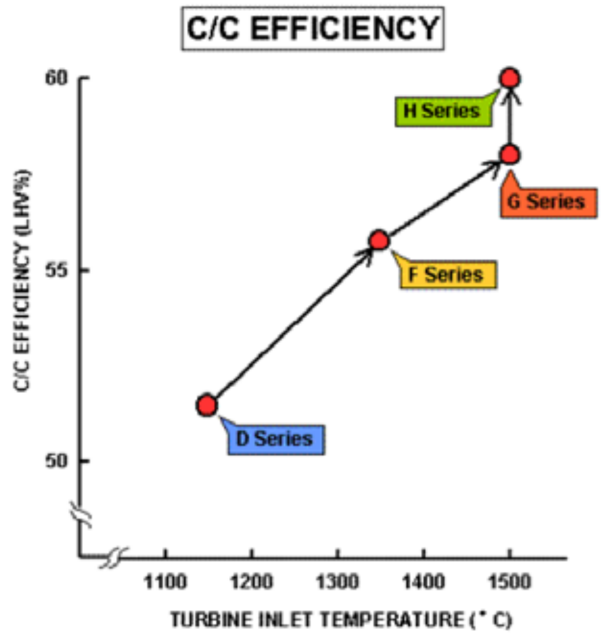
Figure 8-1, 2011 Electricity Statement of Opportunities, AEMO

The rapid growth in wind generation can be attributed to renewable energy support schemes such as the Mandatory Renewable Energy Target (MRET) scheme and its more recent incarnations. By contrast the rapid growth in gas generation can be attributed to the growth of the east coast gas industry, improvements in gas turbine technology, a need for flexible generation in the NEM and investor expectations of future carbon pricing. The gas projects use either open cycle gas turbine or combined cycle gas turbine configurations, with the latter being more expensive and more suited to higher capacity factor operation. In

[5] AEMO defines "committed" as "generation that is considered to be proceeding" and "advanced" as "generation at an intermediate stage of development" (AEMO 2011 ESOO, p xxix).

some cases, investors have made provision to convert from open cycle gas turbine to combined cycle gas turbine configuration if warranted by future NEM price behaviour.

The following figure illustrates the steady improvements that have been made in combined cycle gas turbine efficiency, with a number of manufacturers now claiming at least 60% (LHV[6]) conversion efficiency when burning natural gas as illustrated in the figure.



Source: Mitsubishi Heavy Industries
(http://www.mhi.co.jp/en/products/detail/efficiency_and_power_output.html)

Looking further into the future, a 20-year assessment of the investment impact of possible future carbon price trajectories and socio-economic scenarios in the 2010 NTNDP concluded *"AEMO's modelling indicates that a moderate to high carbon price will result in significant levels of generation retirement in Victoria's Latrobe Valley, with subsequent replacement by gas-powered generation"* (NTNDP, p 10).

The following quotations from Garnaut Climate Change Review Update 2011 Update Paper 8 (Version 31/3/11) provide some additional indications as to how "best practice" electricity generation in the NEM might evolve in the context of a carbon-pricing regime:

- *Switching from coal to gas-fired electricity generation will assist Australia in meeting national emissions reduction targets over the next decade (p 12)*
- *Reforms associated with the creation of the National Electricity Market have created a wholesale electricity market in Eastern Australia that is well placed to deal with the change in relative prices that will flow from a carbon price (p 19)*

[6] Higher heating value (HHV) takes into account the latent heat of vaporization of water in the combustion products, and is useful in calculating heating values for fuels where condensation of the reaction products is practical (e.g., in a gas-fired boiler used for space heat). HHV assumes all the water component is in liquid state at the end of combustion. Lower Heating Value (LHV) assumes that condensation does not take place because it is impractical. (based on Wikipedia article on 'heat of combustion').

- *A carbon price will change the relative costs of different sources of generation according to the emissions intensity of each (p 19)*
- *The open market for generation capacity will allow new lower-emissions generators to enter the market, according to the price signals, if it is profitable to do so. (p 19)*
- *In the current environment, investment in coal-fired power, despite being the lowest cost form of baseload generation, is unlikely given its high emissions intensity and subsequent exposure under a future carbon price… Investors are minimising risk and therefore capital costs by investing in Open Cycle Gas Turbine technology to meet demand, rather than Combined Cycle Gas technology, which could be optimal under a carbon price. It is worth noting that investors have recently been selecting open cycle gas models that can be quickly adjusted to combined cycle operations (p 19)*
- *The Update examined closely the options for emissions-intensive baseload generators to operate flexibly to generate value as the carbon price increases. Within economic limits, there is considerable scope for flexibility. Recent analysis commissioned by the Update has confirmed that even for older brown coal facilities such as Hazelwood and Yallourn in the Latrobe Valley, it is possible for generators to operate intermittently in the summer months to meet demand on hot days (p19 & 20).*

The last point is explained further in Garnaut Update Paper 8 Box 4, p 20 (below) and it is interesting to note that Garnaut Update Paper 8 preferred the low-capacity factor option to the "Contract for Closure" program that has since been implemented[7].

Box 4: A non-baseload future for brown coal-fired generators

The Update commissioned Sinclair Knight Merz to evaluate the potential for brown coal-fired generators to operate in a non-baseload capacity in the future. The report found that for the Hazelwood and Yallourn facilities, there are no known technical reasons which would prevent the facilities operating in non-baseload capacity—that is, limiting operations to when demand is likely to be high in summer.

The report confirmed that these plants:

- can be completely shut down for a number of months in a year;
- can be recalled from a state of complete shutdown in approximately two weeks;
- can operate intermittently for several days at a time on a relatively short recall period of about three days—a shorter recall period of less than three days could be achieved at added expense; and
- the total maintenance costs would be much lower under such a regime because the plant overall will run less.

More complex staffing arrangements would be required.

This analysis confirms the technical viability of coal-fired baseload plants operating as a plant with intermittent production—as coal-based plants do overseas and have done in the past in Australia.

Source: SKM 2011.

(Garnaut 2011 Update Paper 8, p 20)

[7] http://www.ret.gov.au/energy/clean/contract/Pages/ContractforClosure.aspx.

The Australian Government released "A Cleaner Future for Power Stations" Discussion Paper on 30 November 2010[8], which proposed "best practice emissions standards for new coal-fired power stations" and "CCS-Ready standards" including an upper negotiating limit for GEI of 0.86 tCO2-e/MWh and a requirement to retrofit CCS technology "within an appropriate time" to all new coal-fired generators.

Table 1 from the discussion paper (reproduced below) sets out the estimated emissions-intensity of new entrant coal and natural gas power stations. Note that the DGDP is included in the table as IGDCC (Brown Coal) with a GEI (generated) of 0.78 tCO_2-e/MWh, whereas IGCC (Black Coal), a comparable process for black coal (drying is not required), is expected to have a significantly lower GEI (generated) of 0.7, similarly ultra-supercritical black coal is expected to have a GEI (generated) of 0.69-0.71.

Table 1: Type, and estimated emissions-intensity of new entrant power stations

Technologies	***Fuel type***	***Estimated emissions-intensity*** **tCO_2-e/MWh** ***(as generated)***
Subcritical	Brown	0.901 - 1.376
Subcritical	Black	0.808 - 1.069
Supercritical (ac)	Brown	0.93
Supercritical (wc)	Brown	0.99
Supercritical (ac)	Black	0.88
Supercritical (wc)	Black	0.84
Emerging technologies expected emissions-intensities		
Ultrasupercritical (ac)	Brown	0.86
Ultrasupercritical (wc)	Brown	0.83
Ultrasupercritical (ac)	Black	0.71
Ultrasupercritical (wc)	Black	0.69
Emerging technologies expected emissions-intensities		
Ultrasupercritical CCS (ac)	Brown	0.04
Ultrasupercritical CCS (ac)	Black	0.06
Oxy Combustion	Black	0.093*
IGCC	Black	0.70
IGDCC	Brown	0.78**
IGCC CCS	Black	0.06
Emissions- intensity of alternate base load power plants		
Combined Cycle Gas Turbines	Natural Gas	0.37
Open Cycle Gas Turbines	Natural Gas	0.62

*Source: Derived from ACIL Tasman. *EPRI **Victorian Government Climate Change White Paper.*

ac= air cooled, wc = water cooled.

("A Cleaner Future for Power Stations" Discussion Paper, p 6)

Stakeholder submissions (available on the web site) in response to the paper include:

[8] http://www.ret.gov.au/energy/sustainbility_and_climate_change/domestic_climate_change/cfps/Pages/a-cleaner-future-for-power-stations.aspx

- *"Standards for coal plants should be considered in the context of a time perspective of plant lives of 40-50 years as experience has shown. By 2050 it is reasonable to expect that reductions of 80% or more in carbon emissions will be necessary to stabilize global C02 concentrations and limit temperature rise. According to the Garnaut Report, Australia's "full participation" on the 450 and 550 parts per million (ppm) C02-e scenarios would reduction emissions reductions for 2050 from 2000 levels of 90 and 80 percent respectively… Requiring new coal plants be carbon capture ready does not provide a guarantee that these plants will actually implement carbon capture and sequestration within the operating lifetime of the plant… We therefore believe that Australia needs to adopt a regulatory framework that provides a greater certainty of achieving substantive and more definitive reductions of C02 than CCS readiness alone provides… With the Canadian and Californian examples in mind, GE believes a requirement for new coal-fired power stations to achieve equivalency with CCGT[9] on average over a specified "life" of the plant or otherwise require the plant to either curtail or cease operation would strongly motivate investment in both improved coal power station performance and regional development of C02 storage" (GE Australia and New Zealand, 10 January 2011)*

Thus GE Australia and New Zealand proposes that emission intensities achievable by coal-fired power stations without CCS, including IGDDC brown coal (the Dual Gas project), should not be considered 'best practice' except for low capacity factor duty, which is consistent with Garnaut 2011 Update Paper 8. Note that the GE submission claims "More than a quarter of the world's electricity is generated using GE technology".

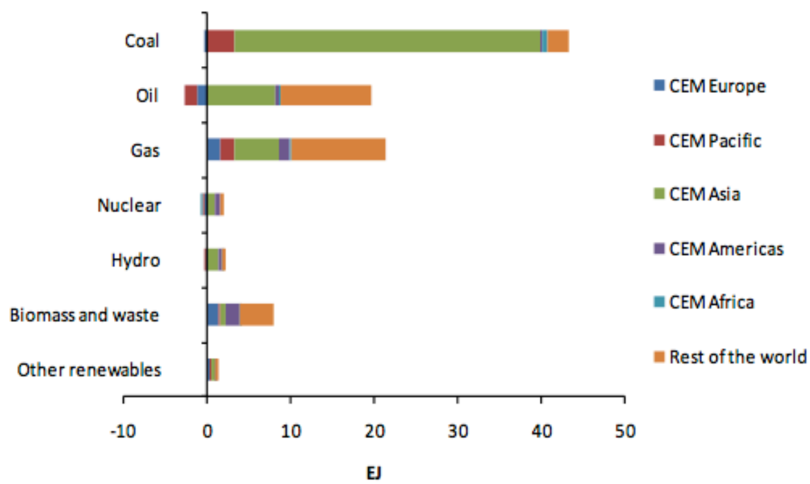
The International Energy Agency (IEA) "Clean Energy Progress Report" (April 2011, available from www.iea.org) provides an international insight on the development of "clean energy" generation:

> *Clean energy technologies came into their own during the last decade. Implementation of energy -efficiency (EE) measures is improving. Renewable energy has seen 30% to 40% growth rates in recent years, due to market-creating policies and cost reductions. Carmakers are releasing the first set of a new wave of electric vehicles (EVs) and are attracting customers. But formidable challenges remain. These developments show that many clean energy technologies are gaining momentum. However, not all of the news is good. Despite the tremendous growth seen in this sector, demand for traditional fossil ‐ based energy has outpaced demand for clean energy (Figure 1).*
>
> *To achieve the clean energy revolution that has been called for, the current double ‐ digit growth seen by renewable energy must be sustained for the long term. Energy ‐ efficiency efforts must provide the right incentives for utilities, industry and consumers to invest, and must verify savings through improved monitoring and reporting. Advanced biofuels and electric vehicles must ramp ‐ up dramatically. Government funding commitments to large ‐ scale demonstrations for CCS and smart grids must be allocated. In short, achieving a sustained clean energy pathway on the global scale will require significant scale ‐ up and acceleration.*

[9] The GE submission proposes that CCGT equivalency be defined as 0.4 tCO_2/MWh.

Table1 (below) includes an updated assessment of the current gaps faced by key clean energy technologies in terms of deployment requirements compared against the BLUE Map scenario and public investments in RD&D. (IEA Clean Energy Progress Report, April 2011, p 11) (IEA Clean Energy Progress Report, April 2011, p 11)

Figure 1. Incremental total primary energy supply in CEM and the world, 2000-08



Note: CEM Europe is Denmark, Finland, France, Germany, Italy, Norway, Spain, Sweden and United Kingdom. CEM Pacific is Australia, Indonesia, Japan and Korea. CEM Asia is China, India, Russia and United Arab Emirates. CEM Americas is Brazil, Canada, Mexico and United States. CEM Africa is South Africa.

Source: Unless otherwise indicated, material in figures and tables derive from IEA data and analysis.

Figure1, IEA Clean Energy Progress Report, April 2011, p 11

In Table 1, the IEA report judges that the deployment of renewable energy generating technologies is meeting expectations apart from Geothermal Power Concentrating Solar Power (CSP). On the other hand electricity generation with Carbon Capture and Storage (CCS) is not. With respect to high efficiency coal use and CCS, the IEA report states (p 13):

For the past decade, coal has been the fastest-growing energy source, meeting 47% of new electricity demand globally. This growth has been accompanied by a move toward more efficient, cleaner coal plants worldwide. However, to meet global climate change goals at lowest cost, extensive deployment of CCS is critical: around 100 large-scale CCS projects are needed by 2020, and over 3,000 by 2050. While there are over 70 projects currently planned, it is uncertain how many of them will be realised. The currently available public funding for large-scale demonstration projects (USD 25 billion) is not enough. Delays in funding decisions are caused by a number of factors that governments must address, including the high cost of CCS, lack of public support for CCS, and a need for adequate regulatory frameworks for CO2 transport and storage.

Table 1. Recent deployment growth compared with clean energy targets

Technology	Current rate	Required annual growth to 2020	Current status	Blue Map target 2020
Biofuel	18%	7%	2.54 EJ	5.04 EJ
Biomass power	7%	4%	54 GW	82 GW
Hydropower	5%	2%	980 GW	1219 GW
Solar PV	60%	19%	21 GW	126 GW
Wind power	27%	12%	195 GW	575 GW
Energy intensity of manufacturing	-1.30%	-0.60%	3.73 MJ	3.81 MJ
Geothermal power	4%	7%	11 GW	21 GW
Nuclear power	3%	4%	430 GW	512 GW
CSP	8%	50%	0.6 GW	42 GW
Electricity generation with CCS	Zero projects	3 GW per year	Zero projects	28 GW
Electric vehicles	-	Doubling of sales each year from 10 000 EV/PHEV sales in 2011 to reach Blue Map target	-	7 million sales in 2020

(green)	Achieving or exceeding levels, maintain the course
(yellow)	Progress but more concerted effort needed
(red)	Sizeable gap between deployment and goals

Note: Table compares recent rate of improvement/growth in a technology area against the rate of improvement/growth required to reach the ETP BLUE Map scenario in 2020. Due to gaps in data, different time periods were used. The current rate for wind and biofuels is the annual average growth rate from 2005 -2010. For solar PV, biomass, geothermal, and CSP this period is 2004-2009. The observed trend in energy intensity is from 2005 – 2008. The current rate and status of nuclear includes capacity under construction up to 2015; the required rate is calculated for 2015 to 2020. Required rates are measured from the year of the last complete global data set. The Energy intensity is measured in MJ per USD PPP 2009. Biofuel is measured in energy use from all biofuels in EJ. Electricity generation with CCS includes generation from biomass, coal and gas. Assumes 10 000 EV/PHEV sales in 2011.

Table 1, IEA Clean Energy Progress Report, April 2011, p 12

With respect to efficient energy use, the IEA report states:

> *Energy efficiency is often referred to as an important fuel of the future. By reducing energy demand, improvements in energy intensity are estimated to deliver 30% of primary energy consumption. Public policy has successfully transformed markets for an array of energy ‐ efficient products, including compact fluorescent light bulbs (CFLs), refrigerators, motors and key building components. These successes have been delivered by a set of well ‐ designed and implemented energy ‐ efficiency policies, including building codes, standards and labelling (S&L), energy certification schemes and utility programmes. Nevertheless, significant under ‐ investment in energy efficiency globally results from an array of market, financial, information, institutional and technical barriers. More effort is needed to advance integrated building design and performance, strengthen appliance standards globally in all markets, improve monitoring and verification of labelling and certification schemes, incentivise utilities to invest more in energy efficiency, and provide a competitive framework for industry to invest in the best available technology (BAT). (p 12)*

We can relate the IEA international assessment of "clean energy" to 'best practice' experience in the NEM in the following manner:

- Gas combined cycle plant has largely replaced coal as the "clean" fossil fuel investment option in the NEM.
- Wind and solar PV are being deployed strongly in the NEM in response to renewable energy support policies. No serious operational problems have arisen to date from this development. Moreover, a paper by Elliston et al[10] explored whether 100% renewable generation would have been possible for 2010. To do this, they used 30-minute NEM load data for 2010, scaled-up output from the existing NEM wind farms and used Bureau of Meteorology solar radiation data to simulate the output from concentrating solar thermal (CST) power stations with storage. The existing hydro capacity was retained and gas turbines (assumed to be using biofuels) were used to "fill the gaps". They concluded: *This research demonstrates that 100% renewable electricity in the NEM is technically feasible for the year 2010, meeting the NEM reliability standard with only six hours in the year where demand is unmet. This result is obtained by using renewable energy technologies that are either in full mass production (wind, PV, hydro and biofuelled gas turbines) and a technology in limited mass production (CST with thermal storage).*
- Pears[11] discussed energy efficiency options in his 2005 discussion of alternatives to operating Hazelwood power station, concluding: *A comprehensive strategy that includes energy efficiency (including cogeneration), fuel switching at point of use and renewable energy has the potential to reduce Victoria's conventional electricity use in absolute terms, and avoid the need to operate Hazelwood. However, to achieve this would require strong and effective policies that target both existing and new equipment and buildings, and further reform of the electricity market to provide appropriate price signals to both electricity suppliers and consumers.*
- As yet there are no CCS projects in the NEM and, according to the IEA document previously discussed, no fully integrated CCS power station projects exist anywhere in the world. The DGDP Works Approval Application states (p 16): *This proposed development is the fourth stage of the IDGCC technology development pathway and aims to demonstrate the IDGCC technology at commercial scale. If this fourth stage is successful, the fifth technology development stage is expected to be the combining of the IDGCC technology with carbon capture (CC).* In this context the "CarbonNet" project[12] is also relevant, targeting CO_2 transport and storage in Victoria. However, substantial policy and public acceptability hurdles remain to be overcome. Even if they do become technically feasible, receive funding and function correctly, CCS

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[10] Elliston B, Diesendorf M and MacGill I, "Simulations of Scenarios with 100% Renewable Electricity in Australia", submitted to Solar2011, 49th AuSES Annual Conference, 30 November – 2 December 2011.
[11] A. Pears, *Potential for replacing Hazelwood with alternatives, particularly energy efficiency*, January 2005. www.naturaledgeproject.net/Documents/REPLACINGHAZELWOODWITHALTERNATIVESfinal1a.pdf. Accessed 3/10/11.
[12] http://new.dpi.vic.gov.au/energy/sustainable-energy/carbon-capture-and-storage/fact-sheet-carbonnet-project. Accessed 10/3/11.

power station projects would not eliminate climate change emissions. Rather they would seek to capture, treat and contain or dispose of the emissions with associated risks, an approach that would rank lower on the wastes hierarchy in the SEPP (AQM) than emission avoidance.

Opinion on whether the Dual Gas project should be considered 'Best practice'

In my opinion, the Dual Gas Demonstration Project (DGDP) as proposed in the Works Approval Application should not be considered 'best practice' for the following reasons:

(a) To be classified as 'best practice' a technology should already have been deployed and shown to have desirable qualities compared to alternative technologies in the relevant context.
(b) The relevant context for the DGDP is the National Electricity Market (NEM) with an additional objective of reducing climate change emissions.
(c) With a Greenhouse Emission Intensity (GEI) of about 0.8 tCO_2-e/MWh in dual-fuel mode, the DGDP would have a higher GEI than either gas-combined cycle or renewable energy generation – proven generation technologies in the NEM that have been regularly chosen by investors as commercially viable projects.
(d) In addition, prudential and efficient energy use is a proven option in the NEM that completely avoids climate change emissions.
(e) The DGDP would also have a higher GEI than either ultra-supercritical black coal or IGCC black coal, technologies that are now in the demonstration phase.
(f) Even within the narrow context of IDGCC, the DGDP as originally proposed should not be regarded as best practice. The approved version is an improvement in the sense that it is more closely focused on the use of gasified brown coal.
(g) Modifying the DGDP to use a higher-efficiency class F combustion turbine design would lower its GEI and should be fully explored.
(h) Adding carbon capture, transport and storage (CCS) to the DGDP would reduce its GEI but may not be a practical option yet. Moreover, an integrated CCS project would have environmental risks associated with each stage in the CCS process and would thus rank lower than avoiding emissions in the SEPP (AQM) wastes hierarchy.

Future improvements in conversion efficiency and implementing carbon capture and storage could change the picture.

The Works Approval Application at p 55 states that "HRL is also working with gas turbine suppliers to allow the use of syngas with the more efficient F class turbines in the future, which is expected to result in about a further 12% gain in efficiency". This raises an important question as to whether the project should be deferred until that can be done.

According to the August 2000 World Business Council for Sustainable Development (WBCSD) document *Eco-efficiency – creating more value with less impact*[13], the term 'eco-efficiency' was first used in its 1992 publication "Changing Course".

The August 2000 WBCSD document contains the following statements about eco-efficiency:

> *Eco-efficiency is achieved by the delivery of competitively priced goods and services*

[13] www.wbcsd.org/web/publications/eco_efficiency_creating_more_value.pdf. Accessed 3/10/11

that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity. (p 9)

eco-efficiency is not limited simply to making incremental efficiency improvements in existing practices and habits. That is much too narrow a view. On the contrary, eco-efficiency should stimulate creativity and innovation in the search for new ways of doing things. Nor is eco-efficiency limited to areas within a company's boundaries, such as in manufacturing and plant management. It is also valid for activities upstream and downstream of a manufacturer's plant and involves the supply and product value-chains. (p9)

Others call for eco-effectiveness rather than efficiency, stressing the importance of innovation. We believe they are right to focus on going beyond simply improving existing processes. It does this by changing industrial processes, creating new products and changing and influencing markets with new ideas and with new rules. (12)

Business cannot achieve eco-efficiency alone. Progress requires going beyond internal actions of individual companies; it requires close cooperation among societal stakeholders. Progress also needs society to create an enabling framework that allows individual companies and whole markets to become more eco-efficient. Governments have an important role to play in creating those conditions. (p 22)

Eco-efficiency is not a model for maintaining the status quo. It is a leadership practice aimed at those intending to stay ahead of the curve and meet the future needs of society, natural resource availability and public perceptions. (p 27)

The SEPP (AQM) contains principles that are similar to those enunciated by the WBCSD as outlined in Appendix A.

In accordance with the principles of eco-efficiency enunciated by the World Business Council on Sustainable Development and relevant aspects of the SEPP (AQM), it is my opinion that further consideration of approval of the Dual Gas project should be deferred until (a) it can use more efficient CCGT technologies and (b) it can be designed and, if approved, implemented as part of a fully integrated CO_2 capture, transport and storage project. The project should then be re-considered for approval in the NEM context that exists at that time.

Part 2. Reviews of expert material provided by the EPA and Dual Gas

Documents reviewed in this section:

- Summary document describing IDGCC process description, calculation of greenhouse emissions and best practice, Alex Blatchford, 26 September 2011
- Review of EPA Works Approval Application from Dual Gas Pty Ltd to build and operate the Dual Gas Demonstration Power Station, Maarten J. van der Burgt, May 2011 (redacted)
- Dual Gas Demonstration Project Works Approval WA 67043 Expert Report, Malcolm Mcintosh, October 2011 (Redacted version)
- Dual Gas Demonstration Project Statement, David Walton, 3 October 2011
- Dual Gas Demonstration Project Expert Evidence in VCAT Proceedings, C M (Costa) Tsesmelis, October 2011

Selected quotations from the above documents are contained in Appendix C. They provide background to the following comments and responses.

Summary document describing IDGCC process description, calculation of greenhouse emissions and best practice, Alex Blatchford, 26 September 2011

Comments on the Blatchford report

The Blatchford report claims that an important strength of the technology is its "unique" tightly integrated nature (drying, gasification and transmission of the steam extracted from the wet coal through the CCGT system). While I agree that is an important strength, the integrated nature of the technology may also have weaknesses. In particular, it appears to:

- "Lock in" the use of a particular Class E combustion turbine that is less efficient than more modern Class F, G or H turbine designs and reduces opportunities for competitive procurement,
- Reduce opportunities to capture economies of scale in CCGT (modern high-efficiency CCGT units are often close-coupled combinations of one large combustion turbine and one heat recovery boiler),
- Preclude the opportunity to claim successful deployment of other IGCC technologies as evidence of 'best practice' status.

The Blatchford report notes that the fuel used in the DGDP would be a combination of natural gas and brown coal, with the mix depending on a range of factors. From the perspective of reducing greenhouse emissions, it would be important to minimise the use of natural gas in the DGDP due to its low conversion efficiency compared to modern high-efficiency CCGT technologies, which are already deployed in the NEM (eg Tallawarra – see Figure 9 of the Blatchford report).

The Blatchford report states that GEI figures can be presented on either a 'generated' or 'sent-out' basis, noting that the sent-out power is lower than the generated power due to internal power consumption. However, the report fails to note that, as a result, GEI figures on a 'generated' basis will be lower than those on a 'sent-out' basis. It also fails to note that internal power consumption varies significantly between different generating technologies, making technology comparisons more difficult if 'generated' data is presented.

The Blatchford report states that "*Your assessment of best practice should proceed on the basis that the relevant 'industry sector or activity' is the brown-coal-fired electricity generation industry sector*". However, the Blatchford report describes the DGDP as a dual fuel (brown coal and natural gas) power station as discussed above and presents results in Figure 9 for dual fuel operation (cases 1 to 3).

Figure 9 of the Blatchford report also shows that IGCC based on black coal would have a lower GEI coefficient on a generated basis than any of the three DGDP cases despite their partial firing on natural gas. This is consistent with Table 1 of the "A Cleaner Future for Power Stations" Discussion Paper, which was discussed earlier in this report.

Response to the Blatchford report

I disagree with the Blatchford report interpretation of 'best practice', which in my view should only be applied to technologies that have already been deployed and have been shown to have desirable qualities compared to alternative technologies in the relevant context.

I believe that a number of the conclusions in the Blatchford report are based on the dual fuel configuration of the DGDP (as the project name "Dual Gas" suggests), which is not "pure" brown-coal-fired electricity generation. As a result, I believe that the basis of technological comparison in the Blatchford report should be broader than brown coal.

In my opinion the basis of technological comparison should extend at least to all fossil fuel technologies and, in the context of the NEM, I believe that a reasonable interpretation would include all renewable energy and energy efficiency technologies as well.

Review of EPA Works Approval Application from Dual Gas Pty Ltd to build and operate the Dual Gas Demonstration Power Station, Maarten J. van der Burgt, May 2011 (redacted)

Comments on the redacted van der Burgt report

The van der Burgt report primarily focuses on the gasification aspect of the project, comparing the DGDP process with three others. It concludes, "*presently the DG process is the 'best practice' technology for generating power from brown coal with the lowest environmental impact".* The report also estimates that the sent out GEI for the DGDP using only gasified coal would be "*about 1.05 tons CO_2/MWh"* and that for base load operation, "*DG will not meet the aim of 0.8 ton CO_2/MWh even when this is interpreted as "as generated"*".

Response to the redacted van der Burgt report

In my opinion, the estimates of GEI in the van der Burgt report are not indicative of 'best practice'. The van der Burgt report focuses on the gasification aspect of the process and its analysis of the project as a whole is not as comprehensive as those of McIntosh, Walton and Tsesmelis, which will now be discussed.

Dual Gas Demonstration Project Works Approval WA 67043 Expert Report, Malcolm Mcintosh, October 2011

The Mcintosh report addresses Greenhouse gas emissions, gas turbines, coal gasification and water use (p 3-4). It contains much information that is relevant to this discussion.

Comments on the redacted Mcintosh report

According to the Mcintosh report, the base-load GEI for the DGDP (which uses natural gas for air pre-heating and coal predrying only) is 0.87 generated. If the coal and natural gas contribute to the power output in proportion to their energy input then the GEI of the coal component is 0.89 T/MWh generated.

A GEI of 0.89 tCO_2/MWh (generated) is higher than the (generated) values given for supercritical black coal power stations (0.88 for air cooling, 0.84 for water cooling) in Table 1 of the "A Cleaner Future for Power Stations" Discussion Paper, reproduced earlier in this report. The DGDP can only achieve lower values than 0.89 by natural gas co-firing, an option that would also be available to supercritical black coal power stations. However, as the McIntosh report points out, if gas were to be used for generating electricity in the NEM it would be preferable to use it in a more efficient CCGT power station than as co-firing in a less efficient coal-fired power station – either black or brown coal.

The McIntosh report goes on to discuss current developments in IGCC and likely future technology options. The report expects that more advanced turbine technology will become available for IGCC in the next five years but that this is contingent on commitment to CCS by governments of influential countries. The report notes that "there appears to be a hiatus in the US and Europe as policy decisions by Government on CCS are awaited". This opinion is consistent with the commentary in the IEA Clean Energy Progress Report discussed earlier in this report.

Response to the redacted McIntosh report

The McIntosh report is consistent with a view that the Dual Gas project should be deferred until (a) it can use more efficient CCGT technologies and (b) it can be designed and, if approved, implemented as part of a fully integrated CO_2 capture, transport and storage project.

Dual Gas Demonstration Project Statement, David Walton, 3 October 2011

Comments on the Walton report

The Walton report identifies economies of scale in the DGDP that would be lost if the project was downgraded from 600 MW to 300 MW. However, the McIntosh report noted that the "Works Approval Application states that the second gasifier would only be installed if the first gasifier was successfully commissioned and that any lessons learned would be incorporated into the design of the second gasifier"*.* Thus, the 600 MW version of the project would capture greater economies of scale but apparently at the cost of reducing the contribution of gasified brown coal compared to natural gas firing.

The Walton report stresses the improved cost-effectiveness of combined carbon and sulphur capture compared to separate capture. While the Walton report appears to imply that, as a result, the imposed sulphur capture obligation is a financial burden that would "significantly reduce the commercial viability of the DGDP", the improved cost-effectiveness of combined carbon and sulphur capture can also be used as an argument to defer the project until the DGDP can be developed as one element of an integrated carbon capture, transport and storage project. Moreover, it seems inconsistent to promote the environmental virtues of the DGDP in reducing CO_2 emissions while appearing to be reluctant to reduce sulphur emissions.

In its discussion of the operation of the NEM, the Walton report argues that the DGDP would not displace non-scheduled generation but does have the potential to displace scheduled generation. In particular it states, "the expectation is that the DGDP will displace generators that have a combination of high costs (largely driven by fuel type) and relatively high burden to pay the carbon price under proposed carbon price legislation".

This is a similar expectation to that for gas CCGT. However, the comparative outcome would depend on many factors and in my opinion is hard to predict. For example, I expect that the DGDP operator would prefer to maintain a steady flow through the gasifier. Moreover, while I agree that the DGDP would not displace existing non-scheduled generation, the situation for semi-scheduled generation (eg most wind farms) is less clear-cut with respect to both operation and generation investment. As discussed earlier and more fully in Appendix B, semi-scheduled generating units are treated like scheduled generating units in the NEM if the central dispatch process requires their output to be kept lower than their forecast unconstrained output. Amongst other factors, network flow constraints, load growth and the incentives under future carbon pricing and renewable energy support policies would influence the outcome.

The Walton report makes clear that the DGDP technology is targeted at low rank coal and that it may be particularly appropriate when moisture content is high. The report also makes clear that the technology is still in the demonstration phase and may have applications other than electricity generation.

Response to the Walton report

The Walton report provides little reassurance that the DGDP technology should be regarded as 'best practice' at this stage of its development. As with the McIntosh report, it is consistent with a view that the Dual Gas project should be deferred until (a) it can use more efficient CCGT technologies and (b) it can be designed and, if approved, implemented as part of a fully integrated CO_2 capture, transport and storage project. It also implies that applications other than electricity generation should be considered.

Dual Gas Demonstration Project Expert Evidence in VCAT Proceedings, C M (Costa) Tsesmelis, October 2011

Comments on the Tsesmelis report

The Tsesmelis report makes the following key points:

- the primary purpose of the DGDP is to demonstrate *the ability of the HRL gasifier technology to provide stable and consistent operation and produce syngas of consistent and reliable quality.*
- *One of the technical requirements for demonstrating the scale HRL gasifier within the overall IDGCC power plant - is the ability to fire the GTs with varying syngas composition and to demonstrate sustained maximum syngas firing.*
- *a single "Train" consisting of one Gas Turbine with a Heat Recovery Steam Generator and a single Steam Turbine can demonstrate the technical and commercial viability of*

the HRL gasifier technology
- *there is very little technical risk that a single train being used to "prove" the HRL gasifier technology would be unsuccessful*
- *My provisional opinion is that a syngas-capable F Class gas turbine would represent best technology from an environmental perspective when considering the generation of electricity using syngas produced by the HRL gasifier*
- *F Class turbines capable of firing syngas of the DG syngas quality will certainly be candidates for future IDGCC plants built at this or other locations in Victoria, and other locations where high-moisture brown coal and lignites are available*
- *HRL are currently working with CO2CRC using the HRL Mulgrave facilities to generate syngas for studies of carbon capture.*
- *Almost the total removal of volatile and non-volatile trace elements and organic compounds from the gasification of coal and the subsequent combustion of the resulting syngas are required today in Europe and the USA.*
- *Given the AGR technologies issues discussed above, the IDGCC plant will probably have a different optimised flow scheme depending on whether the plant is: A) designed to be Carbon Capture and Sequestration (CCS) ready from Day I of operations, or B) designed to be CCS ready at some undefined point in time in the future.*

Response to the Tsesmelis report

The Tsesmelis report is consistent with a view that the Dual Gas project should be deferred until (a) it can use more efficient CCGT technologies and (b) it can be designed and, if approved, implemented as part of a fully integrated CO_2 capture, transport and storage project. This is because the Tsesmelis report concludes that:

- *The primary purpose of the DGDP is to demonstrate the ability of the HRL gasifier technology to provide stable and consistent operation and produce syngas of consistent and reliable quality*
- *F Class turbines capable of firing syngas of the DG syngas quality will certainly be candidates for future IDGCC plants built at this or other locations in Victoria*
- *HRL are currently working with CO2CRC using the HRL Mulgrave facilities to generate syngas for studies of carbon capture*
- *Almost the total removal of volatile and non-volatile trace elements and organic compounds from the gasification of coal and the subsequent combustion of the resulting syngas are required today in Europe and the USA.*
- *Given the AGR technologies issues discussed above, the IDGCC plant will probably have a different optimised flow scheme depending on whether the plant is: A) designed to be Carbon Capture and Sequestration (CCS) ready from Day I of operations, or B) designed to be CCS ready at some undefined point in time in the future*

There is thus little point in proceeding with the project until the necessary design work and negotiations have taken place and until a formal proposal can be submitted for a fully integrated CO_2 capture, transport and storage project.

Appendix A: The concept of 'eco-efficiency'

Origin of the term 'eco-efficiency'

According to the August 2000 World Business Council for Sustainable Development (WBCSD) document *Eco-efficiency – creating more value with less impact* [14], the term 'eco-efficiency' was first used in its 1992 publication "Changing Course".

The August 2000 WBCSD document contains the following statements about eco-efficiency:

> *Eco-efficiency is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity. (p 9)*
>
> *eco-efficiency is not limited simply to making incremental efficiency improvements in existing practices and habits. That is much too narrow a view. On the contrary, eco-efficiency should stimulate creativity and innovation in the search for new ways of doing things. Nor is eco-efficiency limited to areas within a company's boundaries, such as in manufacturing and plant management. It is also valid for activities upstream and downstream of a manufacturer's plant and involves the supply and product value-chains. (p9)*
>
> *Others call for eco-effectiveness rather than efficiency, stressing the importance of innovation. We believe they are right to focus on going beyond simply improving existing processes. It does this by changing industrial processes, creating new products and changing and influencing markets with new ideas and with new rules. (12)*
>
> *Business cannot achieve eco-efficiency alone. Progress requires going beyond internal actions of individual companies; it requires close cooperation among societal stakeholders. Progress also needs society to create an enabling framework that allows individual companies and whole markets to become more eco-efficient. Governments have an important role to play in creating those conditions. (p 22)*
>
> *Eco-efficiency is not a model for maintaining the status quo. It is a leadership practice aimed at those intending to stay ahead of the curve and meet the future needs of society, natural resource availability and public perceptions. (p 27)*

Some aspects of the SEPP (AQM)[15] that are directly relevant to 'eco-efficiency'

Clause 6, Policy Aims:

The aims of the policy are to:

(a) *ensure that the environmental quality objectives of the SEPP (AQM) are met*
(b) *drive continuous improvement in air quality and achieve the cleanest air possible having regard to the social and economic development of Victoria and*
(c) *support Victorian and national measures to address the enhanced greenhouse gas effect and depletion of the ozone layer.*

[14] www.wbcsd.org/web/publications/eco_efficiency_creating_more_value.pdf. Accessed 3/10/11
[15] www.gazette.vic.gov.au/gazette/Gazettes2001/GG2001S240.pdf. Accessed 3/10/11

Clause 7, Policy Principles:
The policy is guided by the following principles of environment protection:

(1) *Integration of Economic, Social and Environmental Considerations*
(2) *Precautionary Principle*
(3) *Intergenerational equity*
(4) *Conservation of biological diversity and ecological integrity*
(5) *Improved valuation, pricing and incentive mechanisms*
(6) *Shared responsibility*
(7) *Product stewardship*
(8) *Wastes hierarchy*
(9) *Integrated environmental management*
(10) *Enforcement*
(11) *Accountability*

Considering particularly relevant policy principles in the above list:

Policy Principle (6) Shared Responsibility

(a) *Protection of the environment is a responsibility shared by all levels of Government and industry, business, communities and the people of Victoria.*
(b) Producers of goods and services should produce competitively priced goods and services that satisfy human needs and improve quality of life, while progressively reducing ecological degradation and resource intensity throughout the full life cycle to a level consistent with the sustainability of biodiversity and ecological systems.

Policy Principle (8) Wastes Hierarchy:
Wastes should be managed in accordance with the following order of preference:

(a) *avoidance*
(b) *re-use*
(c) *recycling*
(d) *recovery of energy*
(e) *treatment*
(f) *containment*
(g) *disposal*

Policy Principle (9) Integrated Environmental Management:
If approaches to managing impacts on one section of the environment have potential impacts on another segment, the best practical environmental outcome should be pursued.

Appendix B: Relevant aspects of the National Electricity Act and Rules

The NEM is formally defined in the National Electricity (South Australia) Act 1996, Version 1.1.2010[16] as follows:

- *National electricity market means—*
    - *(a) the wholesale exchange operated and administered by AEMO under this Law and the Rules; and*
    - *(b) the national electricity system; (p23)*
- *National electricity system means—*
    - *(a) the generating systems and other facilities owned, controlled or operated in the participating jurisdictions connected to the interconnected national electricity system; and*
    - *(b) the interconnected national electricity system; (p 24)*
- *Interconnected national electricity system means the interconnected transmission and distribution system in this jurisdiction and in the other participating jurisdictions used to convey and control the conveyance of electricity to which are connected—*
    - *(a) generating systems and other facilities; and*
    - *(b) loads settled through the wholesale exchange operated and administered by AEMO under this Law and the Rules;*

Further to the above, the National Electricity Rules Version 45[17], contains the following definitions that define the activity of "generation":

- *Generating system*
    - *(a) Subject to paragraph (b), for the purposes of the Rules, a system comprising one or more generating units. (p 997-8)*
    - *(b) For the purposes of clause 2.2.1(e)(3), clause 4.9.2, Chapter 5 and a jurisdictional derogation from Chapter 5, a system comprising one or more generating units and includes auxiliary or reactive plant that is located on the Generator's side of the connection point and is necessary for the generating system to meet its performance standards.*
- *Generating unit:*
    - *The actual generator of electricity and all the related equipment essential to its functioning as a single entity.*
- *Generation:*
    - *The production of electrical power by converting another form of energy in a generating unit.*

Interpreting 'best practice' within the context of the NEM legislative framework

The National Electricity Objective clarifies the interpretation of best practice in the NEM[18]:

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16 www.legislation.sa.gov.au/LZ/C/A/NATIONAL%20ELECTRICITY%20(SOUTH%20AUSTRALIA)%20ACT%201996/CURRENT/1996.44.UN.PDF. Accessed 3/10/11

17 www.aemc.gov.au/Electricity/National-Electricity-Rules/Current-Rules.html. Accessed 3/10/11.

The objective of this Law is to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to—

(a) price, quality, safety, reliability and security of supply of electricity; and

(b) the reliability, safety and security of the national electricity system.

Where electricity services are defined in the Law as follows (p 20):

electricity services means services that are necessary or incidental to the supply of electricity to consumers of electricity, including—
(a) the generation of electricity;
(b) electricity network services;
(c) the sale of electricity;
end user means a person who acquires electricity or proposes to acquire electricity for consumption purposes;

Further clarification comes from Chapter 3 of the National Electricity Rules:

Market design principles:
(a) This Chapter is intended to give effect to the following market design principles:
(1) minimisation of AEMO decision-making to allow Market Participants the greatest amount of commercial freedom to decide how they will operate in the market;
(2) maximum level of market transparency in the interests of achieving a very high degree of market efficiency;
(3) avoidance of any special treatment in respect of different technologies used by Market Participants;
(4) consistency between central dispatch and pricing;
(5) equal access to the market for existing and prospective Market Participants;
(6) … (9)

In the above:

- *Market Participant is defined as: A person who is registered by AEMO as a Market Generator, Market Customer or Market Network Service Provider*
- *Market Customer is defined as: A Customer who has classified any of its loads as a market load and who is also registered by AEMO as a Market Customer, and*
- *Customer is defined as: A person who:*
    - *1. engages in the activity of purchasing electricity supplied through a transmission or distribution system to a connection point; and*
    - *2. Is registered by AEMO as a Customer.*

Thus key aspects of 'best practice' in the context of the NEM are:

- *Efficient operation and investment with respect to the long-term interests of electricity consumers, including the integrity of the national electricity system*

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[18] National Electricity (South Australia) Act 1996 Version 1.1.2010, Schedule - National Electricity Law, Part 1 Section 7.

- *Minimisation of distinctions between market participants (generators, customers, network service providers, noting that each of these categories have different obligations under the NER)*
- *Avoidance of special treatment with respect to different technologies used by market participants (technology neutrality)*

In considering the above, it is relevant to note that there is no mention of the following terms in either the National Electricity (South Australia) Act 1996, Version 1.1.2010 or the National Electricity Rules Version 45:

- Peak, intermediate or base load, when used as ways of specifying generator types
- Eco-efficiency or other environmental objectives. However, the Act does define "regulatory obligation' to include "*an Act of a participating jurisdiction or any instrument made or issued under or for the purposes of that Act that relates to the protection of the environment*" (p 28).

However, some distinctions are made between generator types:

- *Market generating unit (NER Clause 2.2.4): A generating unit whose sent out generation is not purchased in its entirety by the Local Retailer or by a Customer located at the same connection point must be classified as a market generating unit. A Market Generator must purchase all electricity supplied through the national grid to the Market Generator at that connection point from the spot market and make payments to AEMO for such electricity supplied at the connection point as determined for each trading interval in accordance with the provisions of Chapter 3.*
- *Non-Market generating unit (NER Clause 2.2.5):* A *generating unit* whose *sent out generation* is purchased in its entirety by the *Local Retailer* or by a *Customer* located at the same *connection point* must be classified as a *non-market generating unit.*
- *Scheduled generating unit (NER Clause 2.2.2): A generating unit which has a nameplate rating of 30 MW or greater or is part of a group of generating units connected at a common connection point with a combined nameplate rating of 30 MW or greater must be classified as a scheduled generating unit unless AEMO approves its classification as: (1) a semi-scheduled generating unit under clause 2.2.7(b); or (2) a non-scheduled generating unit in accordance with clause 2.2.3(b).*
- *Non-Scheduled generating unit (NER Clause 2.2.3): A generating unit with a nameplate rating of less than 30 MW (not being part of a group of generating units described in clause 2.2.2(a)) must be classified as a non-scheduled generating unit unless AEMO approves its classification as: (1) a scheduled generating unit under clause 2.2.2(b); or (2) a semi-scheduled generating unit under clause 2.2.7(b).*
- *Semi-Scheduled generating unit (NER Clause 2.2.7): A generating unit which has a nameplate rating of 30 MW or greater or is part of a group of generating units connected at a common connection point with a combined nameplate rating of 30 MW or greater, must be classified as a semi-scheduled generating unit where the output of the generating unit is intermittent unless AEMO approves its classification as: (1) a scheduled generating unit under clause 2.2.2(b); or (2) a non-scheduled generating unit under clause 2.2.3(b).*

The distinction between market and non-market generating units is primarily about size – the NER permits dispensation for (small) generators from complying with the obligations of market participation on the grounds that the costs incurred by such generators if they were required to do so would outweigh the resulting social benefits.

The distinction between scheduled and non-scheduled generating units is also primarily about size – the NER gives default dispensation for generators rated at less than 30MW from participating in the central dispatch process on the grounds that the costs incurred by such generators if they were required to do so would outweigh the resulting social benefits.

The category of 'Semi-Scheduled' applies to generators with 'intermittent' output. The NER defines 'intermittent' as 'A description of a *generating unit* whose output is not readily predictable, including, without limitation, solar generators, wave turbine generators, wind turbine generators and hydro-generators without any material storage capability.' This category was introduced to accommodate generators that exploit non-storable, variable and uncertain primary energy fluxes of which wind generators are the most important at the present time. Such primary energy fluxes have the characteristic of 'use it or lose it' and so, once the generating unit is in place, it is socially beneficial to exploit the associated primary energy resource when it is available, unless a greater cost is incurred.

In its 2008 rule determination regarding intermittent generation[19], which came into effective in March 2009, the Australian Energy Market Commission (AEMC) gave the following explanation for why the 'Semi-Scheduled' category was introduced and how the category would be treated in the NEM:

> *Large intermittent generators such as wind farms are currently registered as Non-Scheduled Generators because they cannot practically comply with some of the Rule requirements for Scheduled Generators such as following a dispatch target. Wind farms are increasing in capacity and are beginning to have material impacts on network congestion and power system security. This is creating challenges for NEMMCO in efficiently managing the operation of a secure power system. This problem is expected to increase in severity as the growth in wind farm development continues.*
>
> *Under NEMMCO's [rule change] proposal, all new intermittent generators greater than 30 MW would be required to register under a new classification of "Semi-Scheduled Generator", submit and receive dispatch information in a similar manner to scheduled generating units, and limit their output at times when that output would otherwise violate secure network limits.*

According to the Determination, the key policy decisions implemented in the rule are to:

- *include the classification of Semi-Scheduled Generator into the Chapter 2 of the Rules, and allow a Semi-Scheduled Generator to register a number of physical generating units as a single generating unit at the time of registration;*
- *require Semi-Scheduled Generators to participate in the central dispatch process, including submitting offers and responding to dispatch instructions;*

[19] AEMC Rule Determination – National Electricity Amendment (Central Dispatch and Integration of Wind and Other Intermittent Generation) Rule 2008, 1 May 2008. Available at www.aemc.gov.au.

- *allow the control of semi-scheduled generating units using network constraint equations;*
- *require NEMMCO to prepare unconstrained intermittent generation forecast (UIGF) for each semi-scheduled generating unit;*
- *require NEMMCO to publish guidelines that define the information that Semi-Scheduled Generators are required to provide for the UIGF;*
- *require Semi-Scheduled Generators to provide information to NEMMCO for the UIGF, including plant availability for each semi-scheduled generating unit;*
- *require Semi-Scheduled Generators to limit the output from their semi-scheduled generating units to below a dispatch level whenever the generation is limited by the central dispatch process;*
- *require Semi-Scheduled Generators to have the capability to respond to voltage and reactive power instructions from NEMMCO, in accordance with the requirements in the technical standards;*
- *allow NEMMCO to recover regulation frequency control ancillary service costs from Semi-Scheduled Generators in a similar manner to Scheduled Generators;*
- *require NEMMCO to monitor the compliance of Semi-Scheduled Generators; and*
- *include grandfathering provisions for intermittent generating units registered at the date the final Rule determination is published and projects considered committed at 1 January 2008. The committed status of projects will be assessed against a criteria derived from the criteria used by NEMMCO for assessing committed projects for the Statement of Opportunities.*

In summary, this rule has the effect of treating semi-scheduled generation like non-scheduled generation unless the central dispatch process in the NEM requires their output to be kept lower than their forecast unconstrained output, in which case they are treated like scheduled generation.

Achieving 'best practice eco-efficiency' in the NEM

The NEM-specific legislative framework does not, by itself, ensure the NEM delivers eco-efficient outcomes and nor can NEM participants acting on their own. As pointed out by the WBCSD (Appendix A), this would require governments "*to create an enabling framework that allows individual companies and whole markets to become more eco-efficient".*

Prior to electricity industry restructuring, this challenge was at least partly addressed by the concept of Integrated Resource Planning (IRP). Two definitions of IRP are:

- *IRP is the combined development of electricity supplies and demand-side management (DSM) options to provide energy services[20] at minimum cost, including environmental and social costs[21]*.

[20] "energy services include, for example, cooking, illumination, thermal comfort, food refrigeration, transportation, material production and product manufacturing"

[21] Sisher, Jannuzzi and Redlinger, *Tools and Methods for Integrated Resource Planning*, UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, November 1997, http://uneprisoe.org/IRPManual/IRPmanual.pdf. Accessed 3/10/11.

- *Integrated Resource Planning, or IRP, can be thought of as a process of planning to meet users' needs for electricity services in a way that satisfies multiple objectives for resource use.*[22]

The traditional form of IRP can no longer be applied in a competitive electricity industry, as recognised in the Tellus Institute Best Practice Guide:

> *If competitive generation markets are introduced at the retail level, so that energy users purchase power supply services directly from the market, then IRP must be reinvented. It must move to the jurisdictional level, where national or state/province level IRP processes can develop benchmark plans.* (p2)

[22] The Tellus Institute, *Best Practices Guide: Integrated Resource Planning for Electricity*, http://pdf.usaid.gov/pdf_docs/PNACQ960.pdf. Accessed 3/10/11.

Appendix C: Relevant quotations from the expert material reviewed

Relevant quotations have been selected from the following documents:

- Summary document describing IDGCC process description, calculation of greenhouse emissions and best practice, Alex Blatchford, 26 September 2011
- Review of EPA Works Approval Application from Dual Gas Pty Ltd to build and operate the Dual Gas Demonstration Power Station, Maarten J. van der Burgt, May 2011 (redacted)
- Dual Gas Demonstration Project Works Approval WA 67043 Expert Report, Malcolm McIntosh, October 2011 (Redacted version)
- Dual Gas Demonstration Project Statement, David Walton, 3 October 2011
- Dual Gas Demonstration Project Expert Evidence in VCAT Proceedings, C M (Costa) Tsesmelis, October 2011

Quotations from the Blatchford report relevant to this discussion

"*The intention of this report is to provide a summary of the following areas:*

- *The Integrated Drying Gasification Combined Cycle (IDGCC) process and the Dual Gas Demonstration Project (DGDP);*
- *The methods used for calculating the greenhouse gas emissions from the DGDP;*
- *An assessment of best practice with respect to the overall performance of the DGDP." (p 2)*

"The development of the pressurised drying with the off-gases from the gasifier with the patented IDGCC technology is unique amongst the current fleet of IGCC gasification technologies listed in Table 2 and other available gasification technologies. This method of drying the coal eliminates the need for expensive and / or inefficient pre-drying. It also eliminates the need for an expensive and very large syngas cooler, which has a need to operate at high temperatures and pressures. (p11)

In the IDGCC technology air is supplied to the gasifier. All but one of the currently operating IGCC plants are oxygen blown, and operate at high gasification temperatures. This requires the use of an Air Separation Unit (ASU) to produce the oxygen, which increases the capital and operating costs, and also consumes a significant amount of power, reducing the sent out power. (p11)

The DGDP is distinctive and unique compared with other IGCC gasification plants worldwide and allows the generation of power from high moisture content brown coals in a cost effective and efficient manner. (p11)

The fuel mix over the operating life of the DGDPS is expected to be determined primarily by NG prices, electricity prices, plant availability, cost and quality of coal, contractual arrangements for gas supply, the reliability of the gasification process and the price of GHG emission permits. (p16)

Greenhouse intensity (tonnes of CO2-e per megawatt-hour) can be presented on a 'generated' power or on a 'sent out' power basis. The generated power is measured at the generator terminals. The sent out power is the generated power minus the internal (or auxiliary) power *consumption in the power station for electrical demands such as pumps, fans, instrumentation, compressors and lighting. The sent out power is therefore always lower than the generated power. (p 18)*

Your assessment of best practice should proceed on the basis that the relevant 'industry sector or activity' is the brown-coal-fired electricity generation industry sector. (p 21)

Having regard to the overall performance of the plant, it is the author's belief that the performance of the DGDP as a whole constitutes best practice in respect to the sector or activity of power generation from brown coal, and meets the definitions of best practice as set out in the SEPP (AQM). (p39)

Quotations from the redacted van der Burgt report relevant to this discussion

For comparing sent data with existing brown coal fired power stations in Victoria it is required to use only coal as a feedstock. This implies that where in the DG process natural gas is used for XXX, coal derived syngas is used. The outcome of this paper exercise gives a greenhouse gas intensity of about 1.05 tons CO_2/MWh. (p 3)

Summarising it is concluded that presently the DG process is the 'best practice' technology for generating power from brown coal with the lowest environmental impact. (p 3)

For base load operation, DG will not meet the aim of 0.8 ton CO_2/MWh even when this is interpreted as "as generated". Malcolm McIntosh concluded that with the most generous interpretation of "as generated" and the maximum use of natural gas the specification of 0.8 ton CO_2/MWh can be obtained with the DG process (p 17)

Quotations from the redacted McIntosh report relevant to this discussion

The base-load GEI for the DGDP (which uses natural gas for air pre-heating and coal predrying only) is substantially lower than the GEl for existing Latrobe Valley brown coal power plants (0.87 generated compared to 1.12 - 1.4 generated) and it is competitive with that obtained from current German supercritical steam plant (if fuelled with Morwell coal). (p 6)

Dual Gas proposes to meet the GEI standard of 0.8 T/MWh (if required on an 'as generated' or 'as sent out' basis) by adjusting the ratio of coal and natural gas that it uses in the DGDP (the use of more natural gas relative to coal lowers the plant's GEI). (p 6)

IGCC technologies (which include IDGCC) allow for pre-combustion capture of the CO2 and commercial technologies for pre-combustion capture are regarded as near-term as most of the equipment required is being currently used in ammonia plants, refineries and other industrial processes. The Works Approval Application states that the DGDP has been designed to enable the potential retrofit of carbon capture technology and the Works Approval requires the works to provide for the future installation of carbon capture equipment. (p 6)

In my opinion, no gasifier is currently available for the DGDP that would be a reasonable alternative to the air-blown fluidised bed gasifier proposed by Dual Gas that would reduce the environmental impact of the DGDP. (p 7)

In my opinion, an E Class gas turbine is the best turbine that is currently available for use with syngas from the DGDP (in terms of environmental impact). (p 7)

If electrical power is to be generated from natural gas alone, then in my opinion an F class or better gas turbine should be used as it would reduce emissions per MWh of electricity generated (compared to an E class gas turbine). (p 7)

In my opinion, it is likely that a more advanced technology gas turbine will become available in the next 5 years. (p 7)

Dual Gas has only addressed achieving a GEI of <0.8 T/MWh generated. The DGDP as approved under the Works Approval would be expected to meet this requirement. To meet a GEI requirement of <0.8 T/MWh sent-out the propotlion of the energy input to the plant from natural gas would have to be increased to 32% from 21% which was required to achieve 0.8 T/MWh generated. (p 14)

I expect that the GEI of a single train DGDP would be only very marginally higher than that of the two train proposal in the Works Approval Application. (p 14)

lf the coal and natural gas contribute to the power output in proportion to their energy input then the GEI of the coal component is 0.89 T/MWh generated. (p 15)

Other power generation technologies involving pre-drying by the energy efficient WTA technology are being developed or are under consideration for use in modern supercritical boiler plant or future IGCC plant. As these have yet to be demonstrated at commercial scale they have not been included in the comparison (p 15)

HRL is also involved in the CarbonNet proposal, which is a multi-user CO2 capture, transporl and storage infrastructure proposal for the Latrobe Valley sponsored by the Australian Government through its CCS Flagship program. CarbonNet is near potentially suitable storage sites, both onshore and offshore where it aims to store between 3 and 5 mega tonnes of CO2 per annum. (p 16)

The new Kemper County IGCC Project in Mississippi, USA, which has only recently commenced construction for a planned start-up in 2014, is to have pre-combustion carbon capture. The facility is to be designed with a carbon capture system which will reduce co2 emissions by approximately 67 percent. The CO2 is to be compressed and piped offsite where it will be sold for beneficial use and geologic storage via EOR. (p 17)

lt is clearly Dual Gas's intention to test and develop the technology using one train only. The Works Approval Application states that the second gasifier would only be installed if the first gasifier was successfully commissioned and that any lessons learned would be incorporated into the design of the second gasifier. (p 17)

Brown coals, particularly those being mined in the Latrobe Valley, have high moisture contents (typically about 60% wet basis, or 1S0% dry basis) and require drying before processing regardless of whether the power plant is a conventional boiler or a gasifier. The IDGCC technology features a novel integrated drying process to dry the coal before it is introduced into a fluidised bed gasifier. In this technology, the coal is dried while entrained in the hot syngas stream from the gasifier. The dried coal is separated from the syngas via a cyclone and fed ... to a feeder which admits the coal into the gasifier. (p 17)

The technology employed in the E class gas turbine is relatively old and the efficiency is lower than would be obtained from more modern gas turbines. (p 20)

An advantage of the older E class gas turbines is that they are proven in the IGCC application and are likely therefore to provide reliable operation which is important for a project which is demonstrating a new gasification/drying technology. (p 20)

The composition of the syngas is the first technical issue to determine whether a particular syngas can be used to fuel a gas turbine. The composition will determine the specific energy which must exceed a minimum value. The hydrogen content in particular affects the gas turbine combustor design, and moisture content affects the specific heat of the hot flue gas after combustion which drives the turbine section of the gas turbine. As a high specific heat affects blade cooling, the combustion temperature may need to be de-rated (ie reduced for specific syngas compositions). (p 21)

These are technical issues which must be addressed. It may mean that the gas turbine manufacturer has to test the syngas in a test rig in order to be satisfied that the combustion is satisfactory or that the necessary computations/testing is undertaken to ensure that the compressor has an adequate surge margin. A gas turbine manufacturer may not be prepared to provide a gas turbine for use in a specific project unless these tests have been undertaken and the results are satisfactory. (p 21)

Because of the project risk and its impact on obtaining finance for a project, the project proponent would not proceed without commercial guarantees from the manufacturer. On the other hand the manufacturer would not provide such guarantees if there were doubts about whether the turbine will operate satisfactorily in the proposed plant. (p 22)

The primary reason given by Dual Gas for offering to provide a gas turbine for operation on the syngas from the DGDP was that ... were not prepared to undertake the very expensive design and testing associated with the piping, valves, and burners for the syngas. These items are very large relative to those required for natural gas as the volume flow of syngas is large relative to an equivalent energy flow of natural gas because: (a) the specific energy of the syngas is an order of magnitude less than that of natural gas; and (b) the temperature (and moisture content) of the syngas admitted to the gas turbine combustor is relatively high. I accept Dual Gas's claim that it was not able to purchase an F Class gas turbine to operate on syngas from the DGDP. (p 22)

The E Class gas turbines were introduced in the early 1980s, the F Class in the late 1980s and the H class a decade later. As well as having a higher efficiency, the more advanced gas turbines also tend to have substantially larger outputs. (p 23)

In my opinion, if electrical power is to be generated from natural gas alone, then an F class or better gas turbine should be used as it would reduce emissions per MWh of electricity generated (compared to an E Class gas turbine). (p 23)

Considerable development work sponsored by the US DOE, the European Commission and other authorities is being undertaken by the gas turbine manufacturers to have the next generation of H and higher class gas turbines available for future IGCC applications to achieve high plant efficiencies to offset the efficiency penalties of CCS. The developments and associated testing include improving combustion stability, reducing NOX levels, and improving flexibility of operation. The literature available appears optimistic about more advanced technology gas turbines becoming available for IGCC applications. (p 23)

It is likely that a more advanced technology gas turbine will become available in the next 5 years provided that there are incentives for the manufacturers to undertake these developments. The main incentive is that further IGCC plants are built. There appears to be in a hiatus in the US and Europe as policy decisions by Government on CCS are awaited - CCS will be the driver for commercial IGCC development. (p 23)

It is expected that if an F class gas turbine could be used in a future IDGCC plant rather than an E class gas turbine, the GEI al base-load would be 0.77 T/MWh compared with 0.87 T/MWh (p 23).

Quotations from the Walton report relevant to this discussion

Whilst the absolute cost for the proposed 600MW facility will be significantly greater than the approved 300MW, the cost of capacity installed ($/kW) of the approved 300MW facility is estimated to be approximately 23% greater than that for the proposed 600MW facility. Further, there are additional efficiency and operational benefits offered by the proposed 600MW facility (which implements a "2 plus 1" Combined Cycle Gas Turbine ("CCGT") configuration), as compared to the approved 300MW facility (which implements a "1 plus 1" CCGT configuration). Whilst not valued as part of the increased cost of capacity installed ($/kW), the operation and maintenance of the approved CCGT configuration, along with the refurbishment of hot gas path parts and the provision of spare parts, will all result in a higher unit cost of power generated in the case of the approved 300MW facility (comparable to the proposed 600MW facility). This would translate to an increase in the unit cost of power generated by the respective facilities of approximately 12% to 20% ... This additional cost will significantly reduce the commercial viability of the DGDP at either the proposed 600MW capacity or the approved 300MW capacity. (p 4)

The DGDP will be required to register as a 'scheduled' generating unit which will require the DGDP to offer MW and prices to be scheduled and dispatched by AEMO as part of a generation merit order, optimising availability (MW) and prices (S/MWh). The scheduling and merit order will result in AEMO economically dispatching generation to meet and balance real time market demand within the NEM. Under this system the DGDP only has the potential to displace other scheduled generation (such as that from existing coal fired power stations within the Latrobe Valley). It cannot displace 'non-scheduled' renewable generation. (p 5)

The IDGCC technology has the potential to be applied in power generation in any country with reserves of low rank coal, which include China, India, and Eastern Europe. After IDG technology has converted coal into syngas, the syngas can be further refined to produce other products, such as liquids, chemicals and fertilizers (CTX). There is therefore significant commercial potential and value for IDG technology beyond power generation. (p 5)

The generally accepted most beneficial application of gas turbine combined cycle power generation is in the modular form described as "2 plus 1" being two of the same gas turbines ("GT") into one steam turbine ("ST"). (p 6)

The DGDP requires GT(s) capable of burning syngas derived from brown coal which has a completely different constitution and different characteristics to natural gas and to other sources of syngas. Important differences include energy content and water content. These differences affect the resulting volume throughputs to a GT. Accordingly, a GT capable of *burning syngas requires considerable re-design. Dual Gas was ultimately offered redesign and subsequent performance guarantees only in respect of an E Class turbine. (p 8)*

Manufacturers of more efficient F Class GTs would need to see a potential market for the redesign of their GTs to operate on low energy syngas in order to incur the cost and expense. I do not believe that a single GT operating on syngas technology would be sufficient to justify this expenditure. There would need to be clear evidence of a growth in the global market for IOGCC technology in order to provide the commercial incentive to develop the more efficient GTs capable of operating on syngas derived from low rank or brown coal. There is no indication of when OEMs might move into this area for F Class GTs. To my knowledge, the OGOP is the only project with the requirement for GT fuel and handling and combustion modifications for low energy syngas from low rank coal. (p 8)

Carbon capture and sulphur capture require the same or substantially similar equipment and processes and for this reason are ideally captured utilising common plant installed at the same time. (p 10)

an integrated system to capture sulphur and carbon at the same time is less expensive than installing sulphur and carbon capture plant separately. The installation of an integrated system is only $20m greater than installing carbon capture by itself (that is, excluding the plant and equipment required for integrated sulphur capture) (p 10)

installation of sulphur capture plant would be premature prior to the proven operation of the IDG Gasifier to an acceptable degree of success. (p 11)

The DGDP has the potential to displace other scheduled generation with its offer of MW and $/MWh based on low cost brown coal and a reduced carbon intensity (tCO_2-e/MWh) resulting from the use the IDGCC technology. In particular, the expectation is that the DGDP will displace generators that have a combination of high costs (largely driven by fuel type) and relatively high burden to pay the carbon price under proposed carbon price legislation. (p 14)

The IDGCC and gasification technology has potential for expansion in the Latrobe Valley and in any other location in which commercial quantities of low rank or brown coal are situated. HRL has developed the unique technology specifically around brown coal as compared to other gasification technologies which operate on oil, pet-coke and black coal fuel sources. Once brown coal is gasified and the energy is in the form of syngas there is potential not only for higher efficiency power generation but also the creation of other products such as liquids, chemicals and fertilisers (CTX) and hydrogen. Low rank and brown coals are abundant in China, India, and Eastern Europe which are the growth economies of the world. (p 15)

Quotations from the Tsesmelis report relevant to this discussion

The Dual Gas proposal was for the project to be completed in two construction stages. Only when fully operational (completion of Stage 2) would the primary fuel used for power generation be the synthesis gas ("syngas") generated from the gasification of brown coal. The first operational start-up phase would be the commissioning and the performance and acceptance tests of the two gas turbines that would take place using 100% natural gas. (The 2nd gas turbine during Stage 1 would operate for only about one third of the time, on 100% natural gas firing, until Stage 2 construction and commissioning was complete). The second operational start-up phase would follow when the No.l gasifier construction and pre-

commissioning work was complete. The start-up time for the gasifier is unlikely to be less than about 4 to 5 months. This will merge with a "proving" period of operations and tests on the gasifier that may last about 9 months, before the No.1 gasifier design production of syngas is fully integrated into the operating power plant. The third operational start-up phase would then take place at the end of Stage 2 when the No.2 gasifier construction and pre-commissioning work was complete. A shorter start-up time combined with initial operations and tests lasting about 6 months is estimated before the No.2 gasifier design production of syngas would be fully integrated with the now syngas fuelled Dual Gas power plant. (p 11)

One of the technical requirements for demonstrating the scale HRL gasifier within the overall IDGCC power plant - is the ability to fire the GTs with varying syngas composition and to demonstrate sustained maximum syngas firing. This technical requirement is available whether or not Dual Gas complete the project as proposed in the application (ie Stages 1 & 2) or as described by the EPA Works Approval. (p 13)

Gasification technologies are today mature technologies that have evolved through a number of generations since the 1920s. Second and third generation Gasification technologies developed during the 1970s and 1990s and up tothe presenttime, are nowwidely employed at industrial facilities around the world. Leaders in the field include Shell, Sasol-Lurgi, GE Energy, Siemens, Uhde and others. Syngas is a versatile gas which can be used directly as a fuel for gas turbine power generation, and as a raw material to make transport fuels, many different chemicals, as well as synthetic natural gas and hydrogen. Worldwide Gasification Capacity is set to double over the next 5 years to 2016. (p 14)

ln power generation, although there have been increasing escalation costs for materials and equipment that has resulted in significant plant cost increases and cancellation of a number of projects, there is also continued growth in lntegrated Gasification Combined Cycle (IGCC) plants around the world. (p 16)

The HRL lntegrated Drying Gasification Combined Cycle (IDGCC) process is a fluid-bed gasification process connected to a Combined Cycle Power Plant… The gasifier technology for the IDGCC process was designed specifically for high-moisture brown coal from Victoria however other high moisture brown coals and lignites from other parts of the world … HRL coal gasification technology will therefore be applicable for the construction of combined cycle gas turbine power plants using high-moisture brown coals that are abundant in many other parts of the world (USA, China, and Europe)… The integrated coal gasification and drying process also reduces the cost of having to entirely dry the coal separately before feeding the coal to the gasification reactor. The requirement for costly syngas cooling heat exchangers or water quench systems is thus eliminated with the HRL gasifier. The new technology being demonstrated by the Dual Gas project is to see whether or not the scaled-up HRL gasifier can in fact produce a stable and consistent syngas fuel quality and meet its design parameters to feed a Combined Cycle Power Plant. The reason for making this clarification, emphasising that stable and consistent operation of the HRL gasifier at scaled-up size is what has to be technically "proven", is because the HRL gasifier is the only part of the power plant that in subject to a technology License Agreement. The important point is that HRL are not licensing a power plant. A potential licensor of the HRL coal gasification technology in the future could engage any of the major gas turbine and steam turbine suppliers to integrate a Combined Cycle Power Plant "add-on" to the HRL gasifier. (p 18)

One important observation concerning all of the three categories of gasifier described is that whichever technology is selected, the gasifier portion of the plant (described as the "Gasifier lsland") forms the largest and most significant portion of the overall coal{o-syngas-to-power processing facility. The on-stream availability and maintenance issues of gasifiers in IGCC configurations versus initial capital costs, and the number of gasifiers required, are also major considerations in evaluating the best gasifier technology to use in a particular application. Given the limited technical information made available to me on the overall Dual Gas project design and the feedstock properties, in particular the ash/slag behaviour of Morwell and Yallourn brown coals, it is not possible for me to form an opinion on whether the HRL gasifier is the best technology gasifier for generating power from Victorian brown coal with the lowest environmental impacts. Other gasifier options including entrained-flow gasifiers may be possible, although I do not have sufficient information to make that comparison. (p 20)

The two main types of gas turbine that would be appropriate for consideration with the DG plant would be the older syngas-capable E Class and the newer syngas-capable F Class. The F Class has a higher firing temperature, as well as higher efficiency, with power output and pressure ratios higher than the E Class … The potential improvement in efficiency between an F Class and an E Class gas turbine fired on natural gas is reported by Malcolm Mclntosh in his report to be in the order of 12%. This is also the figure quoted in the DG Works Approval Application for the expected gain in efficiency with the use of syngas in an F Class. I agree with these estimates. (p 22)

The DG syngas is produced from air blown coal gasification, and the cooled syngas also contains water (steam), so there will be significant amounts of nitrogen and water vapour in the syngas composition. The issue with inerts, which includes N2, CO2, and H2O in a syngas feed to the gas turbine, is the requirement for bigger gas passages and bigger combustors. Syngas produced from the HRL gasifier will also have a lower calorific value than syngas produced from other gasification processes, because of the high moisture content of the gas and the use of air blast for the gasification. These factors involving increased flows for the same low calorific value gas could potentially mean that major development work would be required for syngas-capable F Class gas turbines, in order to accommodate the Dual Gas syngas. (p 23)

One item that all vendors would want to know concerning the DG syngas quality is whether or not the DG plant will be retrofitted at some point in the future for carbon capture which would involve acid gas removal and would change the syngas composition. There is also the question of whether DG would consider a CO shift reactor for shifting the syngas to capture all the carbon inventory in the syngas. The syngas that will result would then have a much higher hydrogen content (which would be diluted with nitrogen) and little if any carbon monoxide. This future new composition would also be taken into account by the gas turbine supplier in their technical assessments, although high hydrogen syngas fuel capability (60% H2 40% N2) is available today and so this is unlikely to cause difficulties for vendors. (p 24)

My provisional opinion is that a syngas-capable F Class gas turbine would represent best technology from an environmental perspective when considering the generation of electricity using syngas produced by the HRL gasifier … This provisional opinion is based on the proviso that gas turbine vendors are engaged with comprehensive information concerning the expected syngas quality, including burner tests if necessary, and that a genuine dialogue and *co-operation between a buyer and potential vendors is developed... This provisional opinion is also based on the proviso that major modifications to the syngas-capable F Class machines in order to ensure successful application of advanced F- Class for the DG plant, such as bigger passages or combustors, for example, would not be required. lf they were then realistically this would preclude the use of these machines for the time being with the DG plant... A further proviso to my opinion is that for a relatively small start-up power company like Dual Gas, reliability issues and the need to lower the risk of any potential gas turbine problems with the demonstration plant, could present a technical reason why a tried and tested older E Class syngas-capable turbine would be preferred and selected as the best gas turbine technology to use for a single train demonstration plant. (p 25)*

F Class turbines capable of firing syngas of the DG syngas quality will certainly be candidates for future IDGCC plants built at this or other locations in Victoria, and other locations where high-moisture brown coal and lignites are available... The vendors' longer term goal is to also meet the increasing demand for high hydrogen/nitrogen diluent fuels anticipated as pre-combustion carbon capture is installed in new IGCC plants and retrofitted to existing plants around the world. The specialised technology needed to handle the high flame speed and combustion characteristics of high hydrogen fuels is well advanced. All the major vendors have their versions of the G and H Class gas turbines that are more advanced than F Class ... My opinion is that F Class is best technology from an environmental perspective for the generation of electricity from natural gas fired gas turbines, even though there are even more advanced gas turbines (G and H Class) available today or shortly coming onto the market. (p 26)

what in fact is being demonstrated is the ability of the HRL gasifier technology to provide stable and consistent operation and produce syngas of consistent and reliable quality... My opinion is that for a project aimed primarily at proving the sizing-up of a pilot plant gasifier to a sized-up gasifier, this IGCC design template is not necessary. Since each HRL gasifier is linked to a CCGT train there is no reason why a smaller power plant cannot be used to help "prove" the HRL gasifier technology (p 27)

my opinion is that a single "Train" consisting of one Gas Turbine with a Heat Recovery Steam Generator and a single Steam Turbine can demonstrate the technical and commercial viability of the HRL gasifier technology... My opinion is that there is very little technical risk that a single train being used to "prove" the HRL gasifier technology would be unsuccessful (p 28)

HRL are currently working with CO2CRC using the HRL Mulgrave facilities to generate syngas for studies of carbon capture. They are evaluating solvent absorption, membrane separation and pressure swing absorption. The program's goal is to reduce the technical risk and cost of pre-combustion capture for power plants that use coal gasification as the core technology. (p 29)

emissions standards in the US and Europe have become more stringent in recent years with regard to the main pollutants (SO2, NOx, CO, and particulates). Almost the total removal of volatile and non-volatile trace elements and organic compounds from the gasification of coal and the subsequent combustion of the resulting syngas are required today in Europe and the USA. (p 34)

Given the AGR technologies issues discussed above, the IDGCC plant will probably have a different optimised flow scheme depending on whether the plant is: A) designed to be Carbon

Capture and Sequestration (CCS) ready from Day I of operations, or B) designed to be CCS ready at some undefined point in time in the future… For a plant designed for CCS from Day 1 the AGR would be designed for the removal of H2S and CO2 as separate streams… lf the plant was being designed for CCS from Day 1 the need for adding additional steam for the raw gas shift would need to be considered. (p35-36)