# Submission to the
# Senate Alternative Fuels Enquiry

15th July 2006

by

**DUT Pty Ltd**

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D R Cummings and DUT Pty Ltd have more than 40 and 30 years involvement, respectively in process design, research and development work on advanced fuel production and utilisation systems. DUT has collaborated with World-leading fuel processing plant manufacturers and manufacturers, engine and turbine designers and research groups supporting these industries. DUT has been involved with the initial design, development, manufacture and demonstration of advanced coal and gas-based energy systems including-

Pressurised Fluid Bed Combustion of Coal
Advanced Black and Brown Coal Gasification Systems
Advanced prototype CO2 separation and treatment plants
Waste coal-fired Fluid Bed Reformer demonstration plant
Initial conception and development of the IDGCC process for brown coal
The AIDG process for black and brown coal
The HARD-HAT cycle for Coal Seam Methane-based power generation
High efficiency methanol production cycles
Conceptual design of the 90% efficient SOFC-D-GT methanol to power system
Laboratory and industrial-scale demonstration of methanol-fuelled diesel engines

DUT's and D R Cummings involvement in fuel and energy system developments is summarised in the attached "DRCCV Senate Peak Oil Committee" document.

This submission outlines how Australia can :-

- Eliminate the need to rely on crude oil imports
- Deal with a probable "Peak Oil" supply problem
- Safeguard and support Australia's transport industry
- Develop new internationally competitive fuel manufacturing industries
- Meet new transport-related ultra-low emission rules
- Expand Australia's coal-based export income
- Eliminate GHG emissions allied to coal-based liquid fuel manufacture
- Drastically reduce transport-related toxic and GHG emissions
- Make maximum use of Australia's principal renewable energy resource
- Meet these needs with Australian-sourced IP
- Use this IP to secure further financial benefit for Australia

This submission covers the principal aims of The Senate Inquiry into Australia's Future Oil Supply and Alternative Liquid Fuels outlining means for Australia to

(a) Meet its transport fuel requirements from coal and CSM (Coal Seam Methane)

(b) Export of coal-based energy for overseas stationary and transport fuel needs

(c) Enable coal-sourced fuels to drastically reduce power and transport emissions.

(d) Create a new ultra-low emission fuel production industry and infrastructure which could be a dominant Australian manufacturing and employment industry

(e) Eliminate Australia's current reliance on crude oil for its transport requirements,

(f) Enable coal-based stationary and mobile power system GHG emissions, in most cases, to be lower than those possible from oil and or gas.

(g) To be able to incorporate, on a massive scale, solar energy (arguably Australia's dominant source of renewable energy) and use infrastructure created by steps (a) to (f) to be able, when appropriate, to move to almost 100% renewable energy.

Coal+CSM to Methanol production facilities would be logically located in country/rural areas making those areas centres for "next generation" fuel manufacture and lowest fuel cost centres from which fuel would be distributed to urban centres and to coastal areas for export. Coal and Solar-based energy production would be a logical basis for major inland growth in Australia.

**DUT asserts that**

There is a sound technical, thermodynamic and strategic case to support Methanol as the preferred future alternative fuel.

Today methanol can fuel existing engines with some increase in engine efficiency with major reductions in SOX, NOX and particulate emissions. If required Australia's existing high performance workshops could, at low cost, readily convert most cars and light commercial vehicles for 100% or high concentration methanol fuel.

Methanol can today, at low cost and at very high efficiency, via know Zeolite or Zeolite-like catalysts, be reformed into 80% diesel and/or aviation turbine fuel with a 20% high quality gasoline sole co-product, enabling methanol-based liquid fuel production to by-pass the need for refinery processing and pass directly into the crude oil-based fuel distribution system.

Unlike Fischer Tropsh (FT) synthesis, which has very low conversion efficiencies and requires very large plants to enable economic use of its major co-production of unwanted and low value by-products, methanol synthesis is very efficient and methanol specific with practically no by-product production and it is possible to have an economically viable methanol plant producing less than 500 TPD of methanol (i.e. about 10% of the equivalent throughput of a commercial FT facility.)

**In the late 1960s DRC managed the design and construction of facilities in Schwarzheide (DDR) which enabled the closure of the last remaining coal to FT liquids pant still operating in Europe.**

**In late 2004 DRC/DUT visited Schwarzepumpe (near Schwarzeheide) to inspect the industrial waste to 200 TPD methanol (not FT liquids) plant which incorporated a Noel gasifier which had been operating for almost 30 years on both coal and liquid waste feedstock. (The Noell and Shell gasifiers are arguably the World's most advanced coal-based gasifiers and both are ideally suited to gasification of Australian coals.)**

With a DUT design variation of the new Haldor Topsoe convection reformer it is possible to produce methanol from methane with the excess hydrogen derived from methane reforming enabling a zero CO2 emission allied to gas-based methanol manufacture. This is not technically feasible with FT synthesis.

**FT products invariably have significant CO2 emissions allied to their integrated waste gas-fired power plants. This emission is additional to the major CO2 emissions allied to FT processing of coal-based synthesis gas.**

The major and overwhelming advantage of methanol is that it can simply and at very low temperature be broken down (i) into H2 and CO, or (ii) if water is added, to H2 and CO2.

**Reaction (ii) is the basis for the methanol fuelled PEM fuel cells in the Daimler Benz fuel cell Necar which was driven from the East to West Coast in USA. Methanol-fuelled fuel cell cars have double the fuel efficiency (and 50% of the GHG emissions) and the same operating range as conventional cars.**

A further fundamental advantage of the reversible H2 + CO2 to Methanol reaction which is of major strategic importance to Australia is that, unlike FT synthesis which can only use CO as a reactant, methanol can be produced from waste CO2 from "next generation" coal-based energy systems and, instead of geo-sequestering CO2, it can be reacted with hydrogen produced from solar water splitting (now under development in UNSW) to produce additional methanol.

**The overall coal plus sunlight to methanol reaction does not release CO2 and about half of the produced methanol is, in effect, "liquefied solar power".**

A coal plus sunlight to fuel system would create and provide the infrastructure required for a possible, ultimate shift to a 100% solar-based liquid fuel system.

Few countries have the combination of fossil fuel and sunlight resources and the political stability to enable initial importers of coal and CSM, to progress to coal and sunlight based fuel to then be able to rely ultimately on a storable 100% solar supply.

It is possible today to buy and operate a matchbox-sized, methanol fuelled Sanyo fuel cell to operate a PC, IPOD or Walkman. Its efficiency is low but its weight, operating longevity and operating cost advantages over battery systems are overwhelming.

**The US army is developing methanol fuelled communication systems for "free roving" army units which are far more weight and longevity effective than advanced battery systems but far less efficient that the units being developed for cars. They do, however, clearly signal the arrival of the methanol fuel cell era.**

Methanol is a fully refined fuel, eliminating need for refineries for fuel production and processing. Methanol-fuelled fuel cell systems can reduce transport's overall energy demand and GHG emissions by up to 75% and, coincidentally, eliminate most engine and transmission moving parts and the allied need for maintenance and lubricants.

**Methanol is now recognised as the most cost-effective means to both store and transport hydrogen. Page 11 outlines the basic properties of hydrogen and methanol which supports this view and shows diagrammatically how methanol can enable the storage and shipment of solar energy, which is Australia's largest and incidentally renewable energy resource.**

Methanol as a general or fuel cell fuel will eliminate SOX and particulate emissions and can totally eliminate NOX emissions i.e. transport-sourced urban pollution.

Possibly because of the unique advantage of methanol, methanol's full potential does not appear to feature in discussion papers issued by major oil companies and would probably not feature in their advice to and lobbying of Government. Methanol could be viewed as "the elephant standing in their corporate lobbies".

**Ensuring national access to best available Australian inventions**

The Intellectual Property (IP) i.e. patents and "know-how" which will solve the World's GHG emission, "Peak Oil" and other problems will be of immense value and create new industries and immense wealth for those owning and implementing the IP.

Fuel systems R&D expenditure in Australia is minimal even though energy exports are vital to the Australian economy and this limited R&D expenditure consists mainly of Government grants, tax concessions and the like with the funds passing via semi-Government organisations such as the ACA, CSIRO and coal-related CRCs.

DUT asserts that, as yet, few major Australian-sourced concepts comparable with that outlined in this submission have resulted from these funds. Submissions made to this Committee should enable the Committee to determine if the current channelling of funds to semi-government research organisations has produced the strategic planning and development answers currently being sought by this Committee.

The US has a dominant ownership position in IP and has recognition of patents and IP as a key requirement for new entrants to the WTO. Unlike Europe and Australia US Patent Law is based on the assertion that companies and beaurocracies do not invent and that inventions are made by individuals or small groups. This basic concept and the rights of inventors are incorporated in US law and breaches of patent law, such as theft or plagiarism, are criminal offences in the USA. This has lifted the status of inventors, increased the value and speed of commercialisation of inventions and assisted growth of new "high tech" companies in the USA. DUT has been able to use US law to partially protect its rights and advance its work in Australia.

DUT considers that for Australia to access the best ideas and answers to its problems, such as those posed by this committee, Government should more actively seek out advice from inventors and innovators rather than companies and bureaucracies. To assist this, DUT considers there is a case for Australian Patent Law to closely follow that of the USA.

**Unlike LNG projects, Fischer Tropsh gas-based processes and the new "Jumbo-sized Methanol Plant designs which require major, proven gas resources to enable commercially competitive production of gas-based liquids, new pre-fabricated "packaged" methanol plants can be commercially viable and competitive down to production rates as low as 200 TPD and are ideally suited to CSM producer needs.**

**Whilst "next generation" fuel cell-based engine systems will give Methanol a key role as the optimum fuel in future power generation and transportation systems. It is possible "as of now" to efficiently fuel a range of commercially available cars and heavier vehicles with methanol.**

**A small, commercial, gas-based 200 TPD methanol plant is operated by Coogee Energy in Altona, Australia. New Zealand has gas-based methanol facilities capable of producing in excess of 5,000 TPD of methanol and current world methanol production capacity is in excess of 32,000 TPD and is, at present, increasing by 10% per annum.**

> **The current "World Market" price for methanol in the SE Asian sector is about $(US) 310/tonne. In straight energy terms this is equivalent to diesel at 75c/l (without excise). A CSM or CSM+coal-based methanol plant would be expected to produce methanol at a lower price than this.**

**A NZ-built "Designline" Capstone turbine-powered hybrid bus could be operated on methanol. In city operation it could have "well or coal seam-to-wheel" efficiency (including allowance for night-time top-up of batteries) and related GHG emission level about 80% of that of a conventional diesel fuelled bus. The bus would have zero SOX, zero particulate and ultra-low NOX emissions (significantly below CNG-powered buses).**

**It is DUT's contention that the premium market for initial application and demonstration of methanol fuelling is in the key coal and minerals haulage sector where considerable development work has been done, fuel tonnage per day per vehicle is high and fuel deliveries go direct to end-user, by-passing garages, forecourts and the like. Urban bus companies and farming co-operatives could also be considered for "early commercial demonstration" programs.**

# The following slides are extracts from DUT documents outlining “next generation” power generation and “Advanced Electricity Storage Technology” systems.

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## INTRODUCTION & SUMMARY-A

**Australia’s largest single export is COAL which generated $11 billion in 2004-5 out of a total Australian export revenue of $142 billion.**

**Conversion of this amount of coal to $(A)250/tonne methanol would increase coal export revenue to $55 billion/yr.**

**If CO2 released in the coal-to-methanol conversion is injected into deep gas-prone coal seams-**
- **The CO2 is sequestered and CSM production is assisted**
- **Coal-based methanol production is doubled**
- **Methanol production CO2 emissions are eliminated**
- **Coal-related export revenue increases to $110 billion/yr**

**Coal and CSM based methanol could become the dominant manufacturing industry in Australia.**

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## INTRODUCTION & SUMMARY- C

**Using Methanex November 2005 NY Investor Conference plant cost estimates, methanol produced in NW NSW in a 20,000 TPD coal and CSM-based plant could be landed in California for under $(US) 200/tonne**

**Gas Turbine SOFC units (currently under commercial development) enable Australian mine to US automotive or grid power emissions to be under 0.3 T $CO_2$/MWhr with zero NOX SOX and particulate emissions. Embedded US power costs could be about $(US) 60/MWhr.**

**To match power and automotive fuel costs based on $(US) 200/tonne methanol, high-grade crude oil prices would have to be under $(US) 40/bbl.**

**In energy content (and zero excise) terms $200/tonne methanol is equivalent to (US) 34c/l i.e. (A) 45c/l diesel.**

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DUT has

• Collaborated with Occidental Oil Corp in development of coal to methanol technologies.

• Designed and constructed advanced cryogenic gas and $CO_2$ separation plants.

• Been the co-inventor of the SECV/HRL IDGCC process for Victorian brown coal and the inventor of the DUT AIDG process for black and brown coal.

• Planned and managed a 1992 SECV study to produce methanol from brown coal and sequester surplus $CO_2$ in Bass St oil and gas fields.

• Been granted patents and has patent applications for advanced coal-based power and gasification systems.

• Has developed and applied for patent coverage for means to improve methanol manufacture and utilisation.

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DUT has invented and had granted patents for the initial gas turbine and methanol dissociator combinations.

*(now a basis for a Japanese NEDO development program)*

DUT has also developed and applied for patent coverage for-

• A means to produce and distribute methanol for cost effective ultra low emission embedded power systems.

• The use of such systems and facilities to enable distribution of methanol as an ultra-low emission power and Californian “zero emission” transport fuel

• A simple means to fuel high efficiency diesel engines with methanol with zero sulphur, zero particulate and ultra-low NOX emissions.

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DUT has

- Organised the Burmah-Castrol demonstration methanol fuelled truck and dual fuelling trials at Ricardo Engineering.
- Presented a joint Ricardo / DUT paper on methanol dual fuelling diesel engines at the 1980 Wolfsburg International Alcohol Fuels Conference.
- Presented an Australian coal and methanol marketing strategy at the 1992 AIE “How Sustainable is our Energy Future” conference in Canberra.
- Organised the joint Burlington Railroad / P&O Engineering methanol fuelling tests with an EMD locomotive test engine at South West Research, San Antonio.
- Retained P&O’s rights to the SW Research data.
- Provisional patent coverage on advanced fuelling systems.

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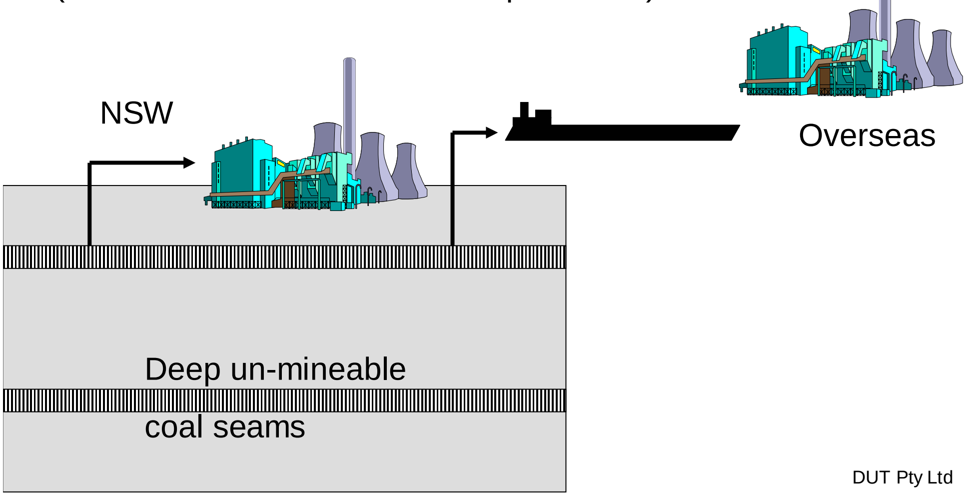
# Current Practice

## Coal-fired Power Generation

Seam to Grid - 0.9 tonnes CO2 per MWhr
(with IGCC 0.7 tonnes CO2 per MWhr)

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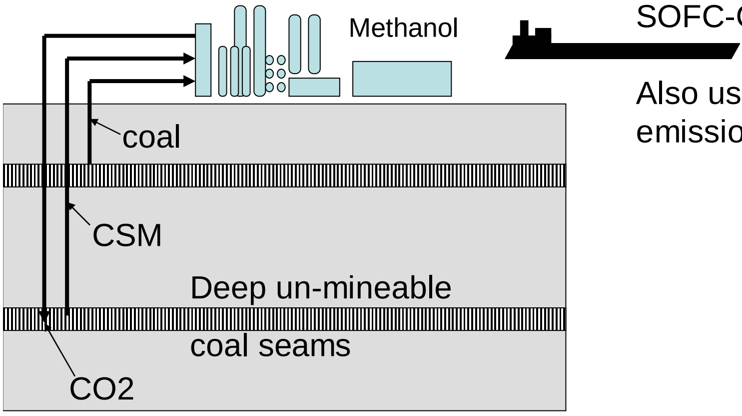
# Future Ultra-low Emission Coal

## Coal-CSM-Methanol-GT SOFC system

Seam to Grid - 0.275 tonnes $CO_2$ per MWhr




To overseas grid via SOFC-GT systems

Also use as ultra-low emission vehicle fuel

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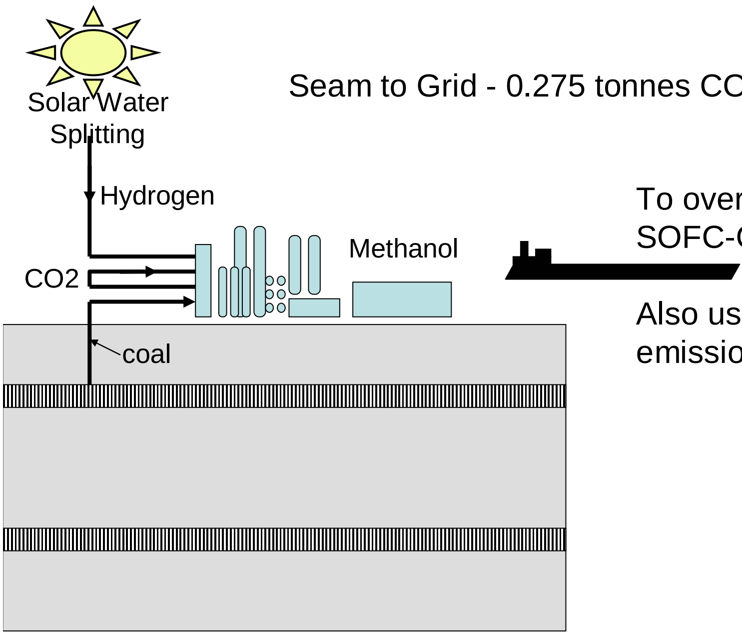
# Future Ultra-low Emission Coal/Solar




Seam to Grid - 0.275 tonnes $CO_2$ per MWhr

To overseas grid via SOFC-GT systems

Also use as ultra-low emission vehicle fuel

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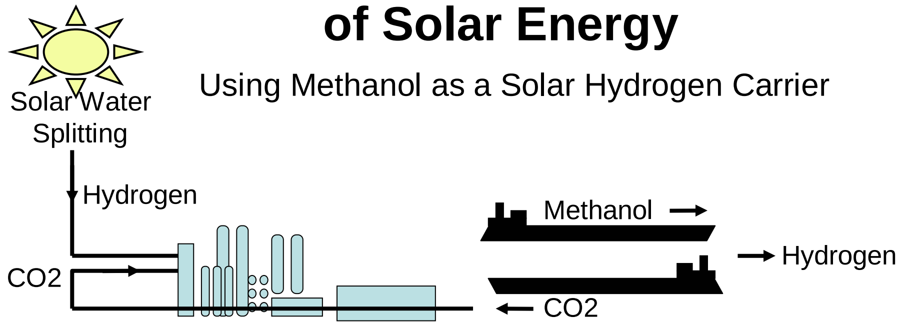
# Future Storage and Export of Solar Energy

Using Methanol as a Solar Hydrogen Carrier




Overseas methanol to hydrogen conversion with CO2 back-haul.

**BASIC (2 way) REACTIONS**

IN AUSTRALIA

$$CH_3OH + H_2O \rightleftharpoons 3H_2 + CO_2$$

IN IMPORTING COUNTRY

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# Why store and transport Methanol instead of Hydrogen?

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Methanol is the lowest cost means to ship and store and a convenient way to utilise Hydrogen.

1 Cubic Metre of Methanol holds 150 kg of Hydrogen.
Alternative storage for 150 kg of Hydrogen requires either-

  33.6 Cu M of 200 atm high pressure storage or
  2 Cu M of super cryogenic (-230oC) storage

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# METHANOL

**Has has fundamental properties that neither higher alcohols (ethanol propanol etc) nor gasoline or diesel fuels possess.**

**(a) Its low temperature endothermic (heat absorbing) conversion to hydrogen and carbon oxides has been a basis for methanol being the fuel of choice for high performance engines. The same property makes it a fuel of choice for "next generation" power systems.**

**(b) Using newly available catalysts methanol can, with the removal of water from the molecule, be simply be re-configured into any one of the compounds making up the World's dominant liquid fuels and basic petrochemicals chemicals. It is the World's new, potential 21st Century building block for liquid fuels and what have been known in the 20th Century as "petro-chemicals".**

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## Methanol Synthesis and Dissociation Basic Reactions

$$CO + 2H_2 \rightleftarrows CH_3OH \text{ (a)}$$

$$CO_2 + 3H_2 \rightleftarrows CH_3OH + H_2O \text{ (b)}$$

Synthesis reactions $\longrightarrow$ are exothermic
Dissociation reactions $\longleftarrow$ are endothermic

Catalysed synthesis and dissociation reactions can take place at as low as 200$^o$C and gas from dissociated methanol can have a 20% higher Heating Value than the methanol feedstock.

Methanol/water mix dissociation via reaction (b) is a basis for providing hydrogen to PEM fuel cell powered motor vehicles.

**(The first PEM fuel cell powered car to cross the USA was fuelled with Methanol)**

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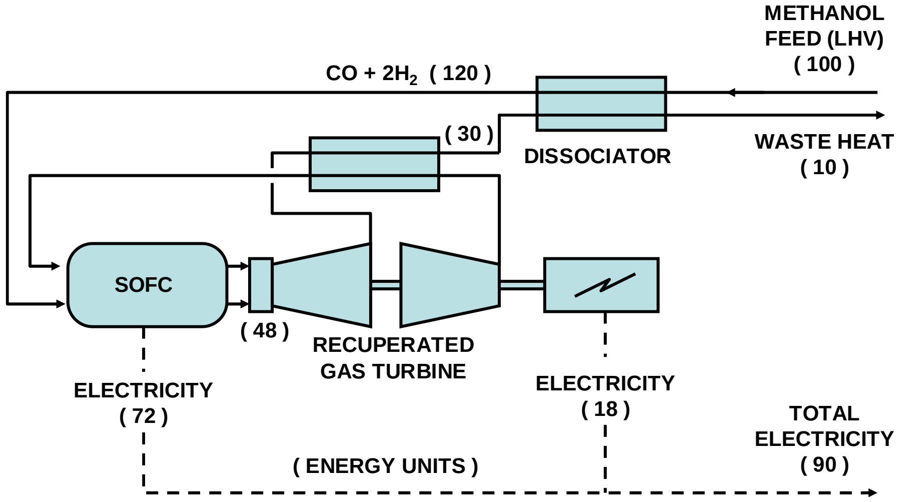
# Methanol Fuelled SOFC Gas Turbine




Presented by DUT in the1992 AIE Canberra Symposium
“How Sustainable is our Energy Future”

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## Rolls Royce 1.0 MW Pressurised SOFC Unit

Rolls Royce predicts up to 70% efficiency for their 1 MW commercial natural gas fuelled pressurised SOFC unit.

Use of methanol instead of natural gas would

- Simplify and lower SOFC unit costs
- Increase system efficiency to the DUT predicted 90+%
- Methanol reforming does not require the 900$^{o}$C+ fuel cell temperature necessary for natural gas reforming

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# Methanol can also be used in- 15

Conventional gasoline engines (same efficiency) or in high CR engines at better than diesel engine efficiencies.

PEM fuel cell (Daimler Benz/Toyota/Mitsubishi) automobiles. (higher efficiency and zero SOX NOX and particulate emissions)

Dissociated Gas Injected (higher efficiency, zero SOX and particulates and ultra-low NOX) DGI Diesel engines.

New (90%+ efficient) dissociator/SOFC/turbine (D/FC/T) stationary units or future heavy transport power units.

D/FC/T powered heavy vehicles and trucks would have 70% lower (than current best) well or mine to wheel overall CO2 emissions and zero SOX NOX and particulate emissions.

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## Why Convert Synthesis Gas to Methanol instead of Fischer Tropsh (i.e. Sasol-type) Liquids?

1. Synthesis gas conversion to Methanol and then to gasoline or diesel using Zeolite catalysts is more efficient and selective than via the Fischer Tropsh catalyst route.
2. Methanol can be converted at low temperature (<350$^{o}$C) to hydrogen and carbon oxides and is an optimum fuel cell fuel whereas conversion of FT liquids requires high (>900$^{o}$C) temperature energy.
3. Methanol, as such, is a premium automotive fuel. US EPA trials demonstrate that a VW Golf methanol-fuelled spark ignition engine is cheaper and more efficient than its diesel equivalent.
4. Methanol is a more efficient and multi-functional chemical feedstock than FT liquids.

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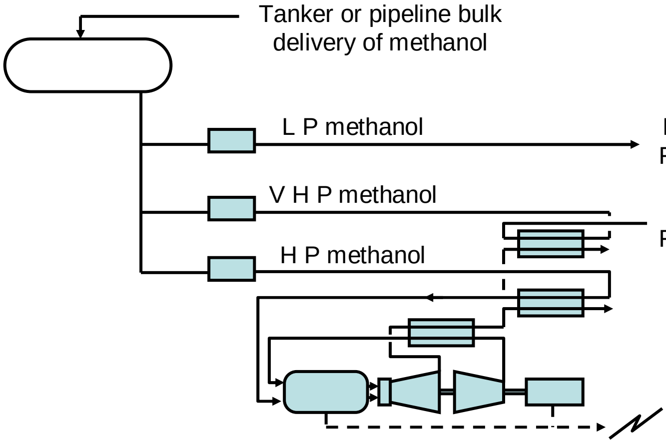
# Methanol-based Low-emission Energy and Fuel Distribution Centre*

* Patent applied for

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# Methanol-based Low-emission Energy and Fuel Distribution Centre

Can be set up initially to supply embedded low-emission power as a high methanol use “core” system suited to extension to fuelling of PEM fuel cell vehicles and methanol fuelled conventional vehicles.

Pending availability of SOFC Gas Turbine systems, initial operation could be based on high efficiency recuperated gas turbines operating on dissociated methanol.

The system complies with the Californian requirement for distributed electricity GHG emissions to also include initial fuel (or power) production.

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# Methanol-based Low-emission Energy and Fuel Costs

• For crude oil-based diesel fuel, used in diesel engines, to compete with SOFC/Gas Turbines fed with $(US) 200/tonne methanol, crude oil prices would have to be about $20/bbl.

• Conventional crude oil-based diesels and power plant could not match the zero NOX, SOX and Particulate emissions possible with methanol-fuelled systems.

• Unlike crude oil-based fuel costs, coal-based methanol contracts could be based on long-term, firm prices.

# D Ray Cummings
# Professional Background and Experience



**1980-2003 Managing Director of DUT Pty Ltd and Isentropic Systems Ltd**

- DUT Basic design and co-patenting of reflux condenser system used for Hartogen's LPG extraction facility at Kincora, Queensland. (Now owned by Origin)

- DUT initiated Costain/TQMS Proposal to WA Government to extract and export LPG from Kwinana (the basis of the Wesfarmers Kwinana facility).

- Conception and management of Costain/TQMS (TQMS being the engineering arm of P&O) proposal to separate and off load LPG from the PNG oil fields via a FPSO unit moored near the crude oil FSO. Rejected by Chevron in favour of reinjection.

- DUT Consultancy to AGL, responsible for initiation of
    - Proposal to NT Government for gas-firing Darwin Power Station.
    - Proposal to strip LNG/LPG/Helium at Darwin
    - Proposal to strip LPG/Ethane from Kurnell Refinery

- DUT Initiation of joint Costain/BHP study to upgrade (Newcastle) blast furnaces to oxygen-only operation with doubled iron output and co-production of synthesis gas for methanol export.

- DUT Conceptual design and detailed studies of Fluid Bed Combustor/ Pulverised Coal-fired boilers to enable low cost use of coal wastes in existing power stations. Formal proposals for commercial demonstration backed by Dorr Oliver, Costain Australia and BHP Engineering. Abandoned due to lack of interest / support from Pacific Power.

- DUT Design of NSW coal waste-fired gas reformer-based facility for methanol production.

- DUT Evaluation of Wakefield (SA) coal-fired PFBC/gas turbine concept for use of very high water content brown coal. Preliminary discussions with ETSA.

- Following approach from Victorian Brown Coal Council re DUT patent and design for coal-fired reformers, joint study with Fluor and VBCC on feasibility and economics of PFBC/Reformer with the evaluation being of relevance advancing brown coal combustion and coal-to-liquid fuel studies.

- DUT Conceptual design of methanol dissociator/fuel cell/ combination to enable conversion of 90% of energy in methanol to electricity.

- DUT Proposal to Victorian Government and study of means, including integrated coal drying and gasification, to significantly reduce greenhouse gas emissions from brown coal-based industrial operations and power production. Concept becoming the basis of the IDGCC program at Morwell (DUT being co-inventor of IDGCC).

- Formation of Isentropic Systems Ltd (30% DUT, 30% EDL, 40% others) as means to promote and market selected DUT-sourced process designs.

- Development and patenting of advanced combustor systems for ultra lean fuel-air mixtures and co-incident design of ultra low NOX burner system. Stage-1 laboratory tests of proposed systems. Design and operation of Stage-2 demonstration rig and design of full-scale combustor. Discussions with turbine manufacturers. Now the basis for the EDL “Carburetted Gas Turbine” (CGT) Development Program and the modified Solar Centaur 3000R turbine installed by EDL at the Appin Colliery.
  ***Demonstration on hold primarily due to start-up procedure and combustion reaction zone design differing from DUT recommendations and combustor heat exchange tubing overheating and failing during start-up.***

- Development and patenting of AIDG process enabling simplification, lowering of cost and improving efficiency of black and brown coal-based IGCC power production systems.

- DUT development and patenting of Power Generation Sewage Disinfection (PGSD) concept based on the flameless combustor incorporated in the CGT system (see above). The PGSD system to be operated in urban areas with ultra-low NOX emissions and very high efficiency (50% with a modified Solar Mercury turbine). PGSD disinfects treated sewage enabling its safe re-use for toilet flushing, external washing and garden use. PGSD enables fresh water use in urban areas to be halved and eliminates the current inland waterway contamination problems in Sydney, Brisbane, Gold Coast and other populous regions.

- Conception and patenting of Coal/Solar-to-Methanol system forming the basis for formation of C.C.Energy Pty Ltd (50% Isentropic Systems, 50% BOC). Recently modified to incorporate the recently emerged UNSW “solar water splitting” technology and further DUT improvements to the concept.

**1975-80 Managing Director DUT Pty Ltd (UK) mainly engaged on special oil / gas separation and gas production/processing conceptual designs.**

- Invited by Preece Cardew to undertake coal feed and ash removal designs for IEA funded Grimethorp 90 MW pressurised fluid bed combustor. DUT recommended slurry feed system over-ridden during design. Reversion to slurry feed following initial operation.

- Management of (GEC, Vickers Shipbuilding, Preece Cardew, DUT) joint studies for UK Government of offshore power generation options for recovery and use of North Sea crude oil-associated gas.

- Conceptual design, patenting and licensing of low cost oil/gas/LPG separation process for Stage-1 of British Gas Wytch Farm (UK) oil field.

- Conceptual design for modification of Ninian A topsides to enable low cost removal and injection of surplus LPG to enable government approval of early start-up with production of low vapour pressure crude oil

- Conceptual and detailed design and patenting of waste coal-fired pressurised fluid bed reformer for natural gas. Funded by Occidental Oil with selected location for test facility in NSW, Australia.

- Conceptual design and patenting of dissociated methanol-fired gas turbine systems.

- Planning and initial supervision of trials of methanol fuelling GM EMD class locomotive diesels with fuel methanol, funded by P&O Shipping and Burlington Northern Railroad, with tests carried out by SW Research, San Antonio, USA.

**1968-75 Manager Petrocarbon and Burmah Engineering Australia, Project Planning Manager Burmah/Castrol UK**.

- Conceptual and final design of CIG Westernport Industrial Gases Complex including proposal to use nitrogen/hydrogen mix for annealing at BHP Westernport.

- Conceptual and detailed design and construction and commissioning supervision of continuous production, submerged arc flux manufacturing plant for CIG Welding Products Division.

- Modification and commissioning of 25 tonne per day “food grade” liquid carbon dioxide plant for CIG.

- Conceptual and final design and construction of 30 tonne per day carbon dioxide/chlorine separation plant for Peko Wallsend synthetic Rutile pilot plant, Mount Morgan, Qld.

- Planning and management of initial studies of joint Kanematsu/Burmah NW Shelf/Dampier crude oil refinery and allied chemical plants as a means of using NW Shelf gas.

- Provision to GEC and Preece Cardew (UK) of gas-based power generation and industrialisation concept (based on Australian NW Shelf studies) as basis for SABIG (Burmah Oil, RTZ, GEC, Preece Cardew) proposal to Saudi Government for oil refining and chemical facilities at Al Jubail.

- Management of review and re-design of Ninian Field (UK North Sea) “topsides” and Sullom Voe facilities to enable co-production and export of LPG.

**1959-68 Process and Project manager for Petrocarbon Developments (UK)**

- Process manager for cracking furnace pilot plant construction and operation in the UK and design of 40,000 TPA naphtha-based ethylene cracking facility for VEB Leunawerke (GDR) (World's largest brown coal-based fuel and chemical facility)

- Process/Project/Commissioning manager at Schwarzheide (GDR) for new herbicide manufacturing facilities enabling shut down of lignite-to-liquid fuels plant. (based on Winkler gasifier-based synthesis gas and Fischer Tropsh technology )

- Project/Process Supervision of wet air sulphur burner system for Chepstow (UK) paper mill sulphite manufacture and allied acid mist agglomeration and removal system.

- Process/Project/Commissioning manager for Polystyrene complex at Onesti (Rumania).

**1956-59 Design Engineer at Simon Carves (UK) (Chemical Plant Division)**

- Process design for sulphur disposal system for the Westfield (British Gas) Lurgi Gasifier-based plant (Scotland). Design of the pilot facility for recovery of $H_2S$ in $CO_2$ contaminated gas as elemental sulphur.

- Process design and commissioning of sulphur and waste acid regeneration plants BP Isle of Grain Refinery (UK).

- Process analysis and review of special mechanical design requirements for a commercial cryogenic deuterium separation plant. Conducted in collaboration with UKAEA Harwell and Petrocarbon Developments (Manchester UK).

- Process design manager for phosphate-based fertiliser plant for Gouldings Fertilisers (Ireland).

- Involvement in the design and evaluation of problems with the early fluid bed (Badishe Turbulent Layer) process for pyrites roasting.

**To 1955 As a junior chemist/engineer with Australian Gas Light Co and part-time Chemical Engineering Diploma student at Sydney Technical College (subsequently University of NSW).**

Presented at the Australian Institute of Energy 1992 Canberra Conference 13-14 April 1992
"How Sustainable is our Energy Future?"

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Abstract

Assumptions that greenhouse gas reductions will be expensive and that gas is automatically superior to coal thus justifying the trans-Australia pipeline are questioned. A profitable way to reduce NSW coal-based emissions by almost 20% and global emissions by 3% is outlined. A variation of low-emission coal-based IGCC technology is proposed with gasification of coal at source and the gas turbine component overseas. Profitable zero emission ironmaking and a methanol-fuelled Solid Oxide Fuel Cell system is outlined. One described SOFC system with 90% fuel-to-power efficiency eliminates almost all emissions, space requirements and visual impact of power stations. The system could also replace diesel engines in rail, mining vehicles and road transport.

## 1.0 INTRODUCTION

Hans Bohm in the 2/91 Siemens Review summarises the current changes in the energy-related engineering industry in stating that "during the last ten years in response to vastly altered requirements which have posted new challenges for power engineering the power plant construction sector has developed so much innovative force the term "conventional power engineering" hardly seems to fit any more.

It is clearly inappropriate to predict future trends on current technology and practices as new commercial developments dealing with current environmental concerns will reduce rather than increase costs. For this reason any claim that emission reductions will, inevitably, be expensive is questionable. However, due to the current unpredictability of the final form of these changes, opposition to forced changes is valid. We need, instead, to question development proposals based on old thinking and try to understand, anticipate and plan for new developments which will bring major growth opportunities rather than supposed contractions.

The following is a selection of concepts which could meet sustainable development guidelines and have major, positive, economic impacts on the Australian economy.

## 2.0 THE ELIMINATION OF COAL-RELATED METHANE EMISSIONS

Methane emissions associated with coal mining account for about 10% of coal's total greenhouse gas emissions and probably in excess of 3% of global emissions and it is now possible, with the use of modified gas turbines to combust and eliminate methane emissions associated with mine ventilation air. (Ref 1). The process enables some coal mining regions, including NSW, to meet the 20% emission reduction target for coal-based industry. Following development and demonstration, the investment required for this reduction in greenhouse gas emissions is expected to be highly profitable. A potential world-wide $20 billion system investment could reduce total global emissions by about 3%.

COAL-BASED POWER GENERATION

Variable and stop-start operation of power stations causes early break-downs in complex coal-fired steam-based plants and limits plant availability to about 80% which, with load variations, brings typical load factors for conventional power plant to under 50% (Refs 2 & 3). Compared to the 80-90+% load factors of metallurgical, chemical and petroleum process plant, the poor inherent use of power station capital requires urgent attention.

The current thrust for lower emission levels from power stations has led to significant modifications to coal-fired power plants to reduce particulate, sulphur and NOX emissions. These changes reduce rather than eliminate emissions and increased complexity exacerbates current availability problems, Figure 1a shows a unit with load factors and capital costs.

Integrated Gasification Combined Cycle (IGCC) plant is a low-emission coal-based power generation option where chemical plant and gas turbine technology is combined to eliminate sulphur and particulate emissions and reduce NOX emissions. However, integration of the gasifier with the generator in accordance with "classical" power station design still ties capital utilisation to power demand and Figure 1b shows a system together with indicative load factors and costs.

Taking a different view of the process made possible by using the IGCC gasifier in its original role to produce methanol and utilising the fact that land and sea-borne transport of methanol is cheaper than coal, a division can be made in the IG and CC sections, as shown in Figure 1c. The IG section can now operate as a continuous process plant at 90%+ load factors and the CC section may have an improved availability due to non-integrated operation with higher utilisation of plant compensating for a higher capital per unit of power processed. The sections can be oceans apart and not incur added costs to power generation charges.

Low global emission power generation by this method would encourage power users seeking minimal local environmental impact to make major investments in Australia.

Any future legislation on emission reductions should allow for relocation of emissions as part of a global reduction program.

4.0 NATURAL GAS USAGE AND THE TRANS-AUSTRALIAN PIPELINE

One perceived way of reducing greenhouse gas emissions is to replace coal with natural gas. In NSW, South Australia and Queensland however, natural gas at source is contaminated with $CO_2$ such that, with gas main leakage as low as 1%, total emissions from gas are equivalent to those from coal and gas losses in NSW are said to be 8% (Ref 2) with the only Eastern State with significant $CO_2$-free gas reserves being Victoria.

Australia's largest gas reserves are offshore and a further distance from energy markets. One means of rectifying this problem, the Trans-Australia pipeline, was first proposed in 1970 and was not, at that time economic or strategically relevant. Today the proposal represents "old" thinking which is questionable on current strategic, economic and environmental grounds.

Investment in a Trans-Australia pipeline requires the early depletion of CO2-contaminated gas sources probably increasing greenhouse emissions in NSW, SA and Queensland in the medium term. The investment would also be wasted if major Eastern gas resources were subsequently discovered, whereas it is now possible to purchase a Floating Production Storage and Offshore loading (FPSO) for LNG based on commercially proven technology with commercial underwriting (Ref 4) having a lower cost than a pipeline and the following strategic advantages.

(a) FPSO can supply all of Australia's dominantly coastal markets.
(b) The FPSO capital plant is recoverable and can access remote offshore gas reserves inaccessible by pipeline.
(c) The FPSO system can divert LNG to export markets should additional East Coast reserves of gas be found.

## 5.0 OFFSHORE METHANOL PRODUCTION

FPSO systems for offshore methanol production are under development and should be available for commercial use within 10 years.

Offshore production and shipping of methanol provides a market flexibility similar to that of FPSO-based LNG. However, although methanol has been considered as a means to transport and market remote natural gas resources and whilst it is cheap to store and transport, its poor conversion efficiency and its strategically inappropriate division of investment has, todate, favoured LNG as the preferred transport medium. Fuel cell technology may change this balance.

## 6.0 LOW-EMISSION IRONMAKING TECHNOLOGY

A major part of Australia's foreign currency is provided by the export of metallurgical coal and iron ore for the global iron and steel industries.

Ironmaking is dominated by coke oven and blast furnace technology (Fig 2) which has major emission problems. Coke production can be a source of gas and particulate emissions and blast furnaces produce a high CO2 emission by-product gas. The high cost of eliminating these problems plus the aim of ironmakers to reduce dependence on metallurgical coals is driving development of processes such as HISmelt, BSC-Hoogovens (Fig 2a), Corex etc. and existing environmental pressures and plant age will require replacement of 80% of existing coke ovens within 20 years (Ref 5).

It is also relevant (ref 6) that oxygen can replace air in blast furnaces with simultaneous major reductions in coke requirements and a doubling of furnace throughput such that half the existing furnaces could be shut down with no loss in output and major reductions in fume and particulate emissions. With new, low-cost gas treatment of oxygen-blown blast furnace off gas, as well as off-gases from newer processes, can be split into CO2 and synthesis gas suitable for methanol production as shown in Fig 2b.

An oxygen-blown blast furnace would more than double its cash flow together with markedly reduced emissions and the co-production of methanol and all CO2 in a form suitable for tertiary oil recovery and incidental disposal in depleted oil fields.

Economics and current (non greenhouse) environmental legislation will force changes to, and possible re-orientation of areas for profitable growth for ironmaking. With current US demand for high-grade, low-emission liquid fuels, its need to boost recoverable reserves of crude oil and availability of depleted oil reservoirs, current environmental pressures could give rise to an economic renaissance of the depressed US iron and steel industry. The total elimination of steelmaking greenhouse emissions would be incidental.

The implications for Australia with such a change range from disaster to bonanza, depending on our elected role in such a change.

## 7.0 COAL WASTE & THE CEMENT, SAND AND AGGREGATE INDUSTRIES

The export of washed coal results in the dumping of 25% of the weight and about 12% of the energy mined as raw coal. The energy waste is equivalent to over 50% of NSW and Queensland's power generation fuel requirements and a means to economically utilise this waste is outlined in Ref 7. It is also possible to simultaneously combust the coal and produce a castable ash-based product to displace and reduce the environmental impact of sand and aggregate mining and cement production as well as eliminating the environmental impact of coal waste dumping. This development could be complimentary to the current crushing and grinding of blast furnace slag as an aggregate and cement replacement product.

## 8.0 THE POTENTIAL FOR SOLID OXIDE FUEL CELLS

Probably the most promising Solid Oxide Fuel Cell (SOFC) utilises a high temperature (1,000$^{o}$C) solid zirconia electrolyte. Australia has major zirconia reserves and CSIRO, together with other companies, is developing SOFC technology.

The cells have a very high efficiency but, within the cell, the fuel must be carbon monoxide and or hydrogen and coal must be first reformed to hydrogen and carbon monoxide. (It is possible to use the SOFC high temperature to reform methane in situ within the cell*.) Gases leave at 1,000$^{o}$C and this energy must be recovered as additional power for maximum efficiency.

Methanol, produced initially from hydrogen and carbon oxides from coal or gas reforming may be simply dissociated back to hydrogen and carbon monoxide and the efficiency loss initially incurred by the gasification or reforming operation during its initial manufacture largely recovered and it is possible to combine a SOFC unit with a gas turbine and methanol dissociator (SOFC-GT-D) as shown in Fig 3. Such a power plant would have a methanol-to-power efficiency of up to 90%, ultra-low NOX and zero hydrocarbon, sulphur and particulate emissions. The unit has one principal (gas turbine) moving part, a low temperature exhaust and does not require steam, water or cooling systems. A 50-100 MW unit could be located in urban locations taking the space and appearance of a residential building and with a pipeline methanol supply eliminate the need for high voltage power transmission where intensive urban development is required. Capital cost should be comparable with CC Gas Turbine units.

The indicative economics of such a plant compared with other IGCC options is shown in Fig 1d and illustrates how emissions and costs allied to power generation can be radically reduced by emerging technologies.

SOFC-GT-D systems could power rail and mine haulage transport systems doubling efficiency, halving CO2 emissions and eliminating known and difficult to eliminate noise, particulate and NOX emissions allied to diesel engines. With elimination of almost all moving parts and mechanical transmission systems maintenance and consumable (lubricant) costs would be slashed and power systems would probably outlast chassis and body components. SODFC-GT-D systems could have a major application in heavy road haulage.

SOFC technology is proven and commercial development appears inevitable and the beneficial commercial and environmental impacts may be an order of magnitude greater than anticipated, even by the developers. With world-wide fuel, key raw materials and equipment sales opportunities, SOFC-related technology could be a key part of a "clever country" future if the opportunity is seized.

With revised and segregated IGCC systems, development of FPSO LNG and Methanol and probable development of SOFC and SOFC-GT-D systems and their related economic and environmental benefits, it may soon be time to question the future economic viability and environmental relevance of traditional gas pipeline and high voltage power distribution systems.

## 9.0 CONCLUSIONS

(a) It is now possible to profitably eliminate methane emissions associated with coal mining and by this method alone reduce coal associated emission in mining regions such as NSW by the current target of 20%. Global greenhouse emissions could be cut by about 3%.
(b) The IGCC systems being developed to reduce environmental and greenhouse emissions allied to coal-based power generation may be adapted so as to locate the IG component at the coal source and whilst capital per unit of installed power increases, improved utilisation of capital results in competitive power costs. Reducing global emissions may, therefore, result in increased emission and investment in Australia. Any emission legislation should allow for such scenarios.
(c) The high wellstream CO2 content of NSW, SA and Queensland gas may increase greenhouse emissions if such gas is substituted for coal.
(d) The proposed Trans-Australia pipeline may be economically, strategically and environmentally inferior to offshore gas development by FPSO systems and coastal shipment of LNG.
(e) New ironmaking processes should reduce ironmaking costs as well as dependence on coking coal and in some locations will result in total elimination of iron and steel greenhouse emissions. These changes could have dramatic effects on Australia's coal and ore industries.
(f) Coal waste dumping in NSW and Queensland represents a resource waste on a grand scale. Recovery and use as power generation fuel is economically viable. It is also possible to react and covert the coal ash to reduce our current demand for sand, aggregate and cement.
(g) SOFC and in particular SOFC-GT-D technology should represent a quantum jump in clean energy technology, raise questions as to the relevance of future gas and high voltage transmission systems and play a major role in Australia's current aim to be a "clever country".

(* Signifies an addition to the original paper)

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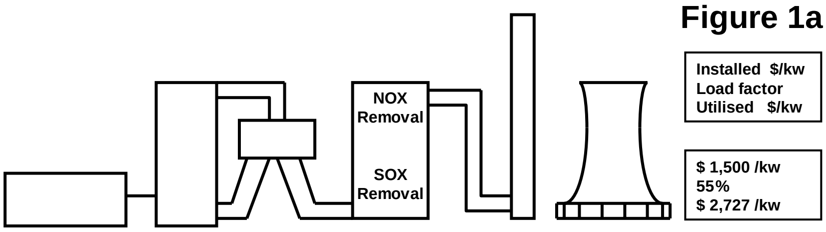
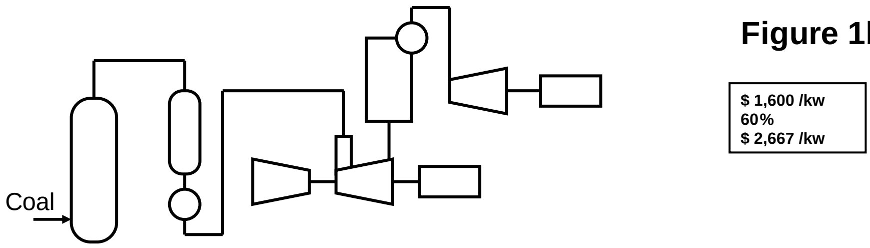
**Figure 1a**




CONVENTIONAL COAL-FIRED POWER STATION

**Figure 1b**




IGCC GENERATION UNIT

**Figure 1c**

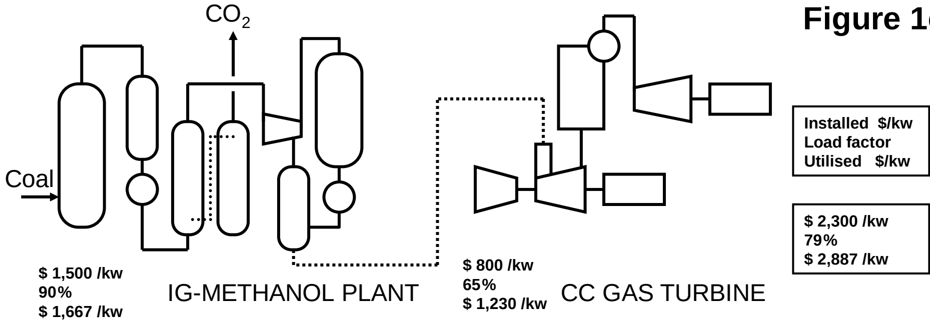



**Figure 1d**

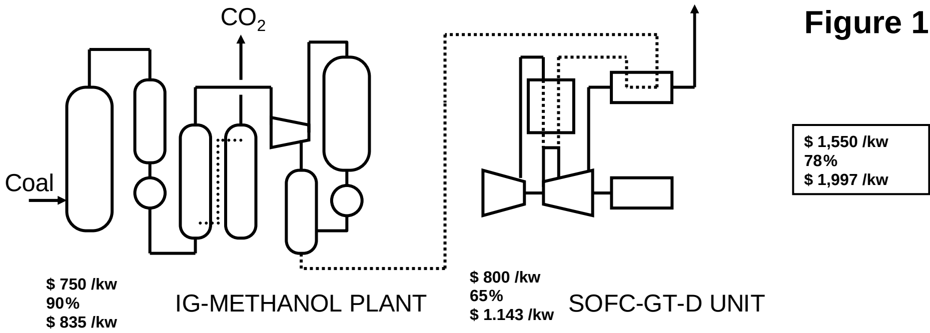
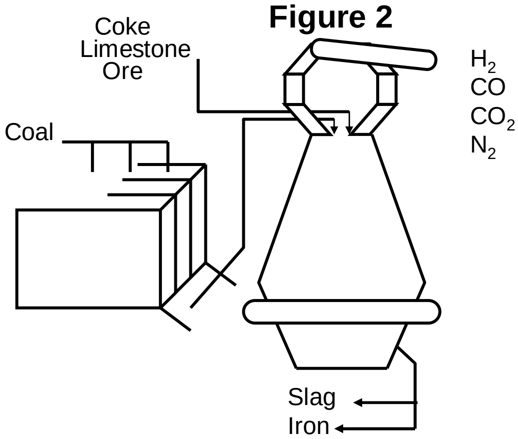
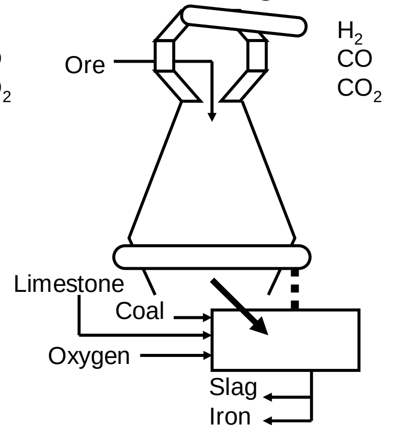



**Figure 2**




CONVENTIONAL BLAST FURNACE

**Figure 2a**




BSC-HOOGOVENS PROCESS

**Figure 2b**

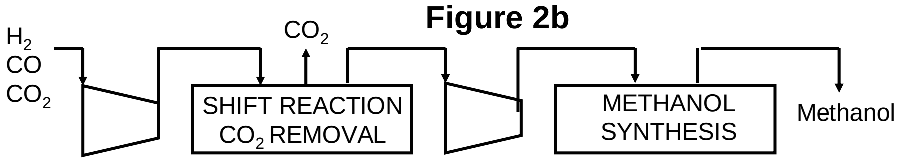


**Figure 3**

**SOFC-GT-D UNIT**