

# **Ultra Clean Coal**

**An Option for Greenhouse Friendly  
Coal Fired Power Generation**

**ACPS Meeting Cessnock, NSW 20 August 2008**



**UCC Energy Pty. Limited**

# ULTRA CLEAN COAL TECHNOLOGY

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- **A cleaner, more efficient way to use coal for power generation.**
- **Substituting coal for natural gas and other petroleum products such as HFO.**
- **Utilising abundant coal resources against insecure and increasingly scarce (expensive) petroleum resources.**



# ULTRA CLEAN COAL (UCC) - 1

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- Both the developed and developing worlds will continue to rely on coal for energy into the foreseeable future
- Climate change concerns and long term access to affordable energy demand cleaner and more efficient utilisation of coal
- UCC is bituminous coal which has been chemically cleaned to remove practically all contaminants
- UCC is a substitute for:
  - natural gas in gas turbine power generation
  - fuel oil in diesel engine power generation
- UCC is also suitable as a fuel for carbon fuel cells (with distinct advantages over hydrogen fuel cells)



# ULTRA CLEAN COAL (UCC) - 2

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- Over A\$45 million has been expended in development of UCC technology, this has included
  - Construction and successful operation of a pilot plant in Australia
  - Combustion testing for gas turbine applications in Japan (MHI)
- The intended progression of commercial applications of UCC for power generation is
  - Short term – large stationary (diesel) engines
  - Medium term – combined cycle gas turbines (CCGT)
  - Longer term – direct carbon fuel cells (DCFC)



# THE ADVANTAGES OF UCC - 1

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UCC has important advantages over petroleum products in power generation:

- Security of supply
  - bituminous coal is in abundant supply in many countries, petroleum is increasingly scarce with remaining reserves concentrated in the relatively unstable Middle East region
- Low cost
  - the cash cost of production of UCC in terms of US\$ per Giga-Joule (GJ) is linked to the cost of thermal coal, the cost of petroleum products is at record high levels and volatile

UCC-fired power generation (whether diesel or CCGT) has important advantages over the most advanced coal-fired power generation

- Greater efficiency
  - 50% – 52% versus 38% - 40% (higher heating value 'HHV')
- Lower greenhouse gas (GHG) emissions
  - 20% reduction in emissions per MW-hour produced



# THE ADVANTAGES OF UCC - 2

## Energy Cost Comparisons For Different Fuels

Prices in US Markets at End June 2008

Fuel	US\$/GJ
UCC (North East US Location)	5 - 6
Natural Gas (NYMEX Contract 1)	12 - 13
Heavy Fuel Oil (< 1% S, NY/LA/Gulf Coast)	17 - 18
No. 2 Diesel (Low S, NY/LA/Gulf Coast)	28 - 30



# UCC

## THE PROCESS



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# THE UCC PRODUCTION PROCESS

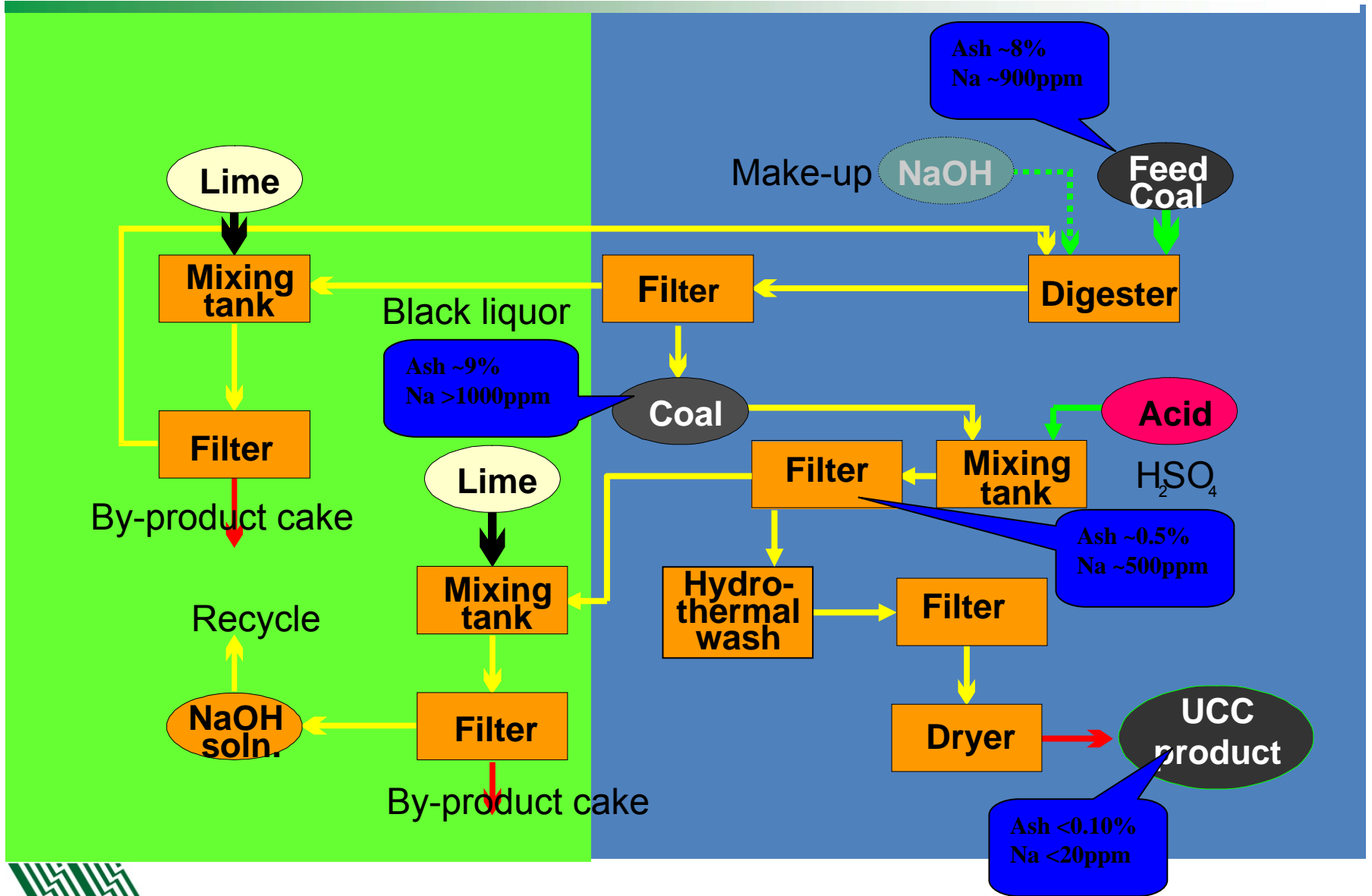
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- UCC is produced by chemically cleaning coal in a process with many similarities to the well-proven Bayer alumina process
- The main process consumables are sulphuric acid, lime and organic solvents; caustic soda is a reagent which is regenerated in the process
- The waste materials are environmentally benign (gypsum & calcium alumina silicates)
- The final UCC product has less than 0.2% ash.
- UCC is available in either briquetted form or as a Coal-Water Fuel (CWF).





# THE UCC PROCESS – SIMPLE BLOCK DIAGRAM

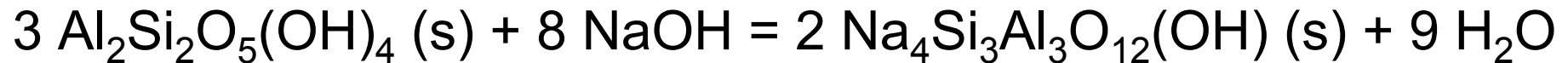
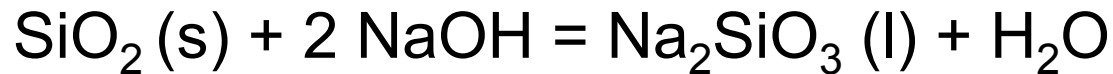


# THE UCC PRODUCTION PROCESS

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## Caustic Digestion

During digestion, the major reactions are the dissolution of silica and formation of solid sodalite as described in the following:



Small amounts of other impurities such as Al, Fe, P and organic carbon may also dissolve during digestion.



# THE UCC PRODUCTION PROCESS

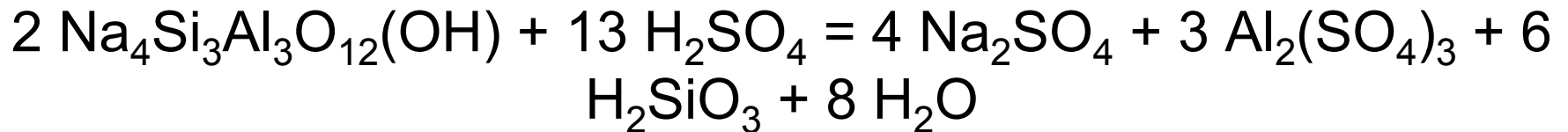
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## Acid Soaking

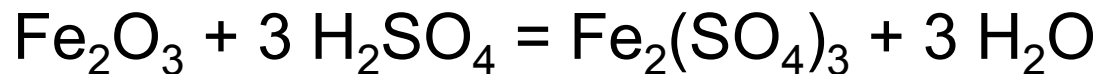
Caustic leached coal is treated with dilute sulphuric acid ( $\text{H}_2\text{SO}_4$ ) in order to perform the following reactions:

### Sodalite Dissolution

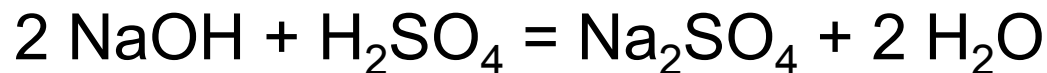
Sodalite is dissolved to give a mixture of sodium and aluminium sulphates plus acid-soluble silicic acid



### Iron Dissolution



### Caustic Soda Neutralisation

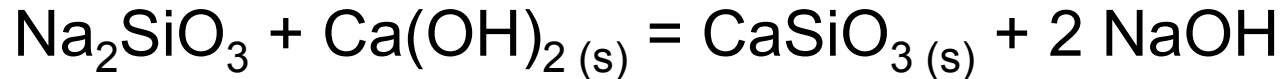


# THE UCC PRODUCTION PROCESS

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## Caustic Soda Regeneration

Filtrate liquor from the caustic digestion filters is treated with slaked lime ( $\text{Ca}(\text{OH})_2$ ) in order to regenerate caustic soda



The liming process simultaneously precipitates the silica dissolved within the digestion process as  $\text{CaSiO}_3$ .

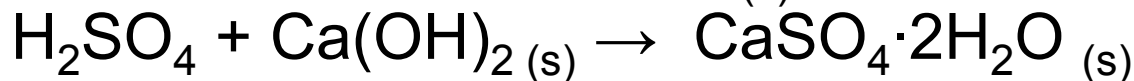
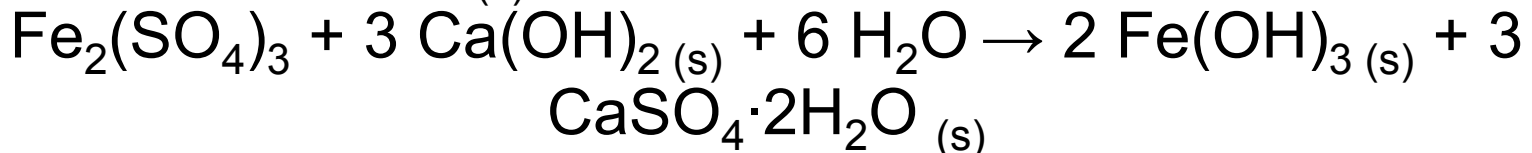
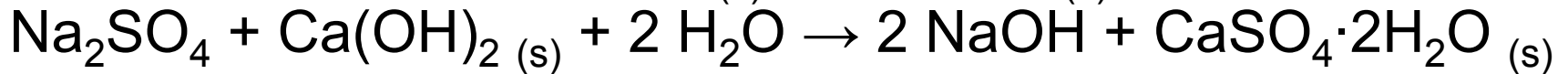
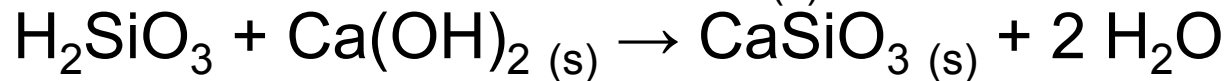
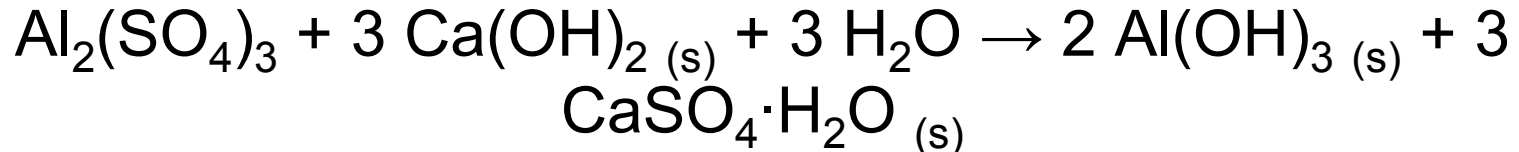
Sodium sulphate generated from pyrite in the coal is also recovered in this step:



# THE UCC PRODUCTION PROCESS

## Acid Causticisation

The aqueous solution of mixed salts from acid soaking is treated with slaked lime to precipitate a mixture of aluminium hydroxide, calcium sulphate, calcium silicate and iron hydroxide.



Within the causticisation reaction, caustic soda is regenerated and impurities such as Al, Fe and Si are precipitated as solids.

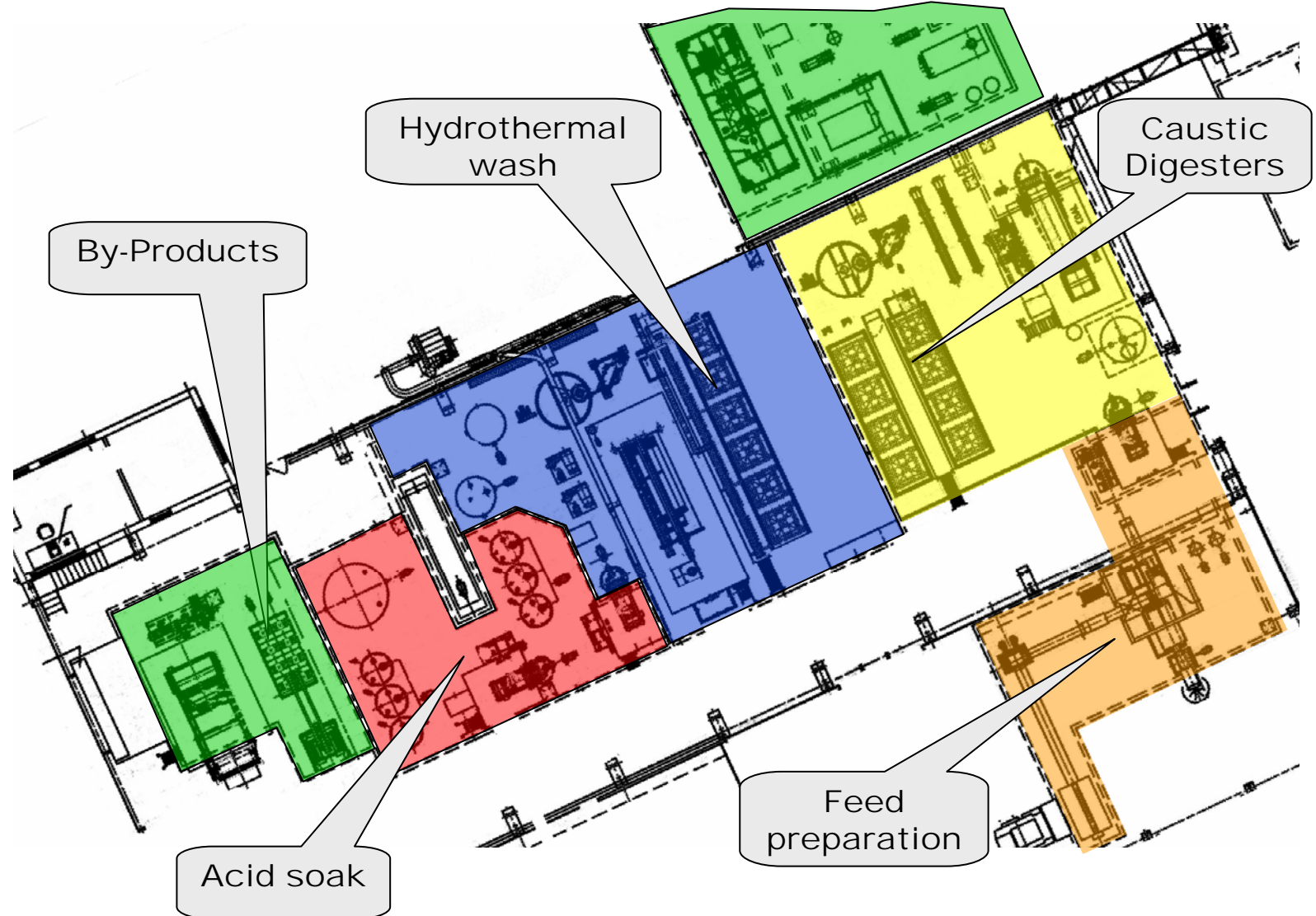


# UCC PROPERTIES

<b><i>Property</i></b>	<b><i>Feed Coal</i></b>	<b><i>UCC 1998</i></b>	<b><i>UCC Current</i></b>
Total Ash	8.3%	0.5%	<0.10
<b><i>Inorganic Content of the coal</i></b>	<b><i>(ppm)</i></b>	<b><i>(ppm)</i></b>	<b><i>(ppm)</i></b>
Si	24,800	78	14
Al	12,300	40	9
Ti	733	513	244
Fe	3383	215	20
Ca	437	36	5
Mg	431	12	5
Na	919	542	<20
Ash fusion temperature <i>IDT</i>	>1500°C	1240°C	>1500°C



# Pilot Plant Layout







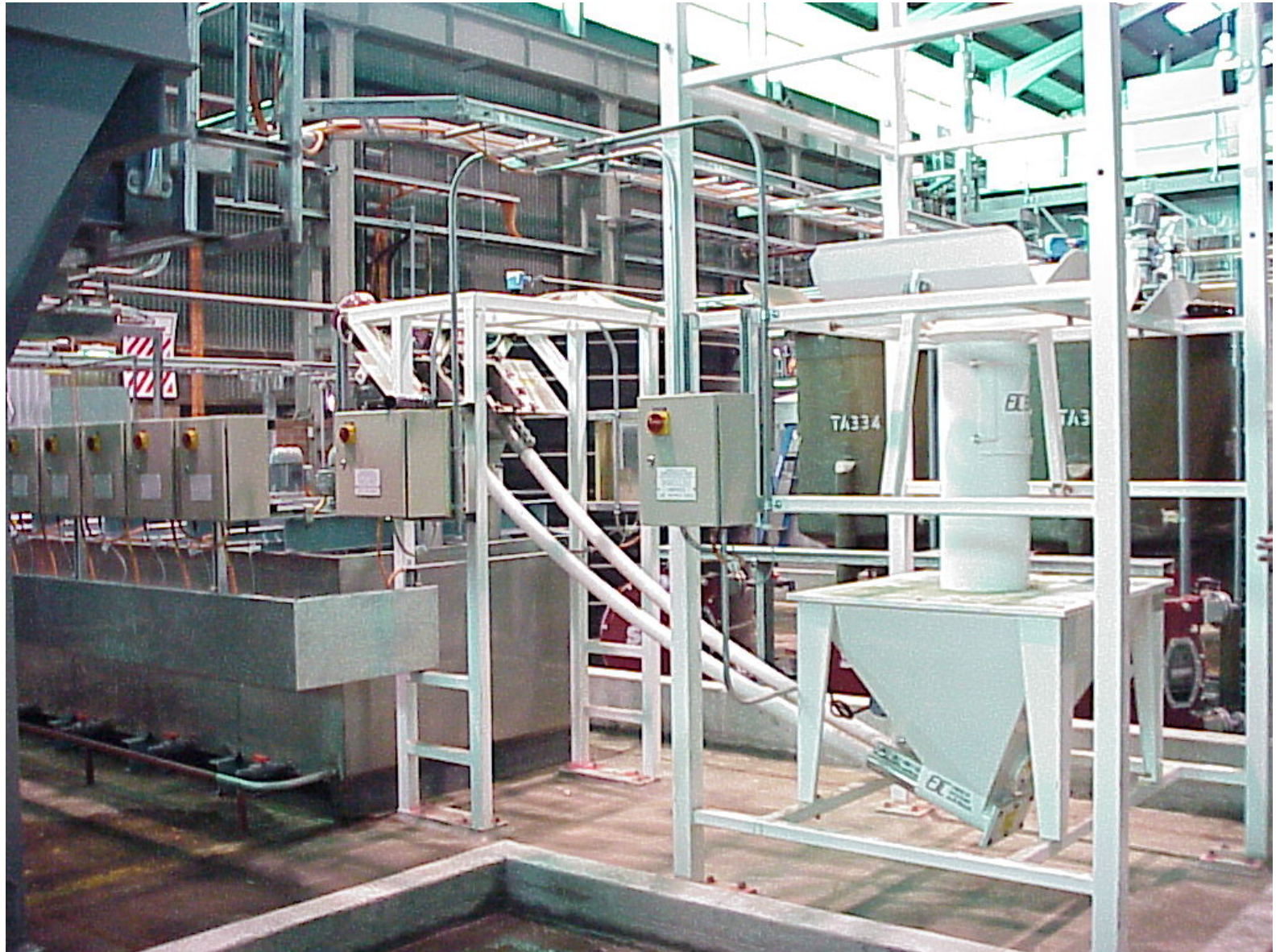
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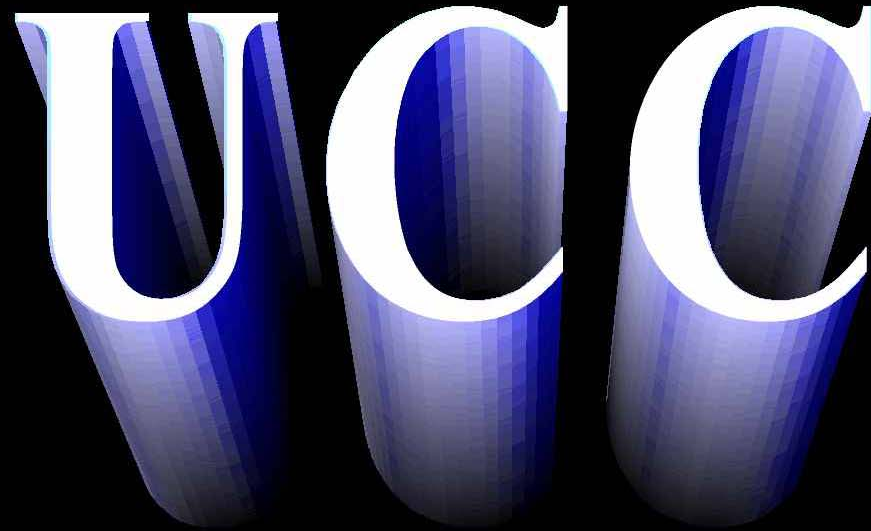


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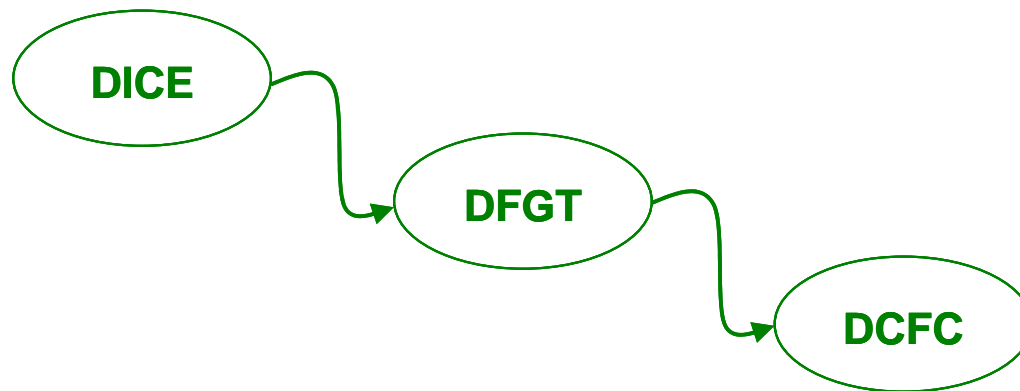
# Fuel Utilization



# UCC APPLICATIONS – The Technology Pathway

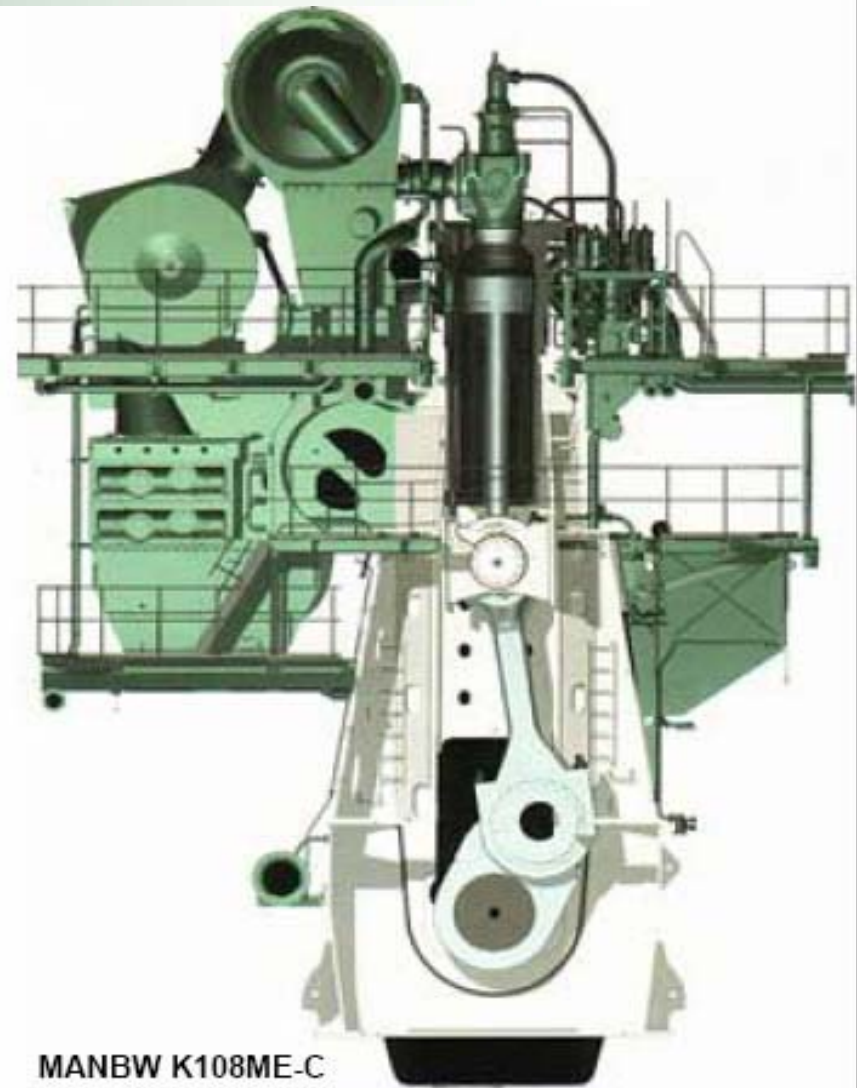
## The Direct Fired Coal Technology Pathway

- currently the most efficient heat engines use direct fired internal combustion - diesel engines and gas turbines
- direct coal firing of these engines will return similar efficiencies - Direct Injection Coal Engines & Direct Fired Gas Turbines – with greatly reduced fuel costs
- DICE and DFGT offer significant efficiency, GHG and emissions advantages over conventional coal-fired power generation
- both types of engines require ultra clean fuels
- direct coal “firing” of fuel cells (Direct Coal Fuel Cell) could ultimately give even higher conversion efficiency



# UCC DICE (DIESEL)

- 54% thermal efficiency (~100 rpm), with very high part load efficiency
- available at up to 97 MW (MANBM)
- most tolerant to fuel impurities, using HFO up to 5% S, 0.5% ash
- long life (typical 125,000h liner life)
- ultra reliable (single engine ships)
- rapid startup (if coolant at 85°C)
- easier to dry cool (coolant at 95°C), unaffected by hot days
- for open cycle, rejected heat could energise PCC (50% with PCC)
- capital cost slightly less than current supercritical pf
- existing electricity generation up to 50 MWe on HFO (and Orimulsion)



MANBW K108ME-C



# UCC DIESEL APPLICATION – DICE

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- Firing with UCC requires only minor and well-understood modification of conventional large diesel engines
- UCC production to less demanding specification than UCC as a CCGT fuel is a possibility
- Lower fuel cost than petroleum-derived fuels and with greater security of supply
- Specific advantages over conventional coal-fired power
  - Lower capital cost
  - Shorter planning, design and construction periods
  - Greater generation efficiency
  - less GHG production





# UCC DIESEL APPLICATION – DICE

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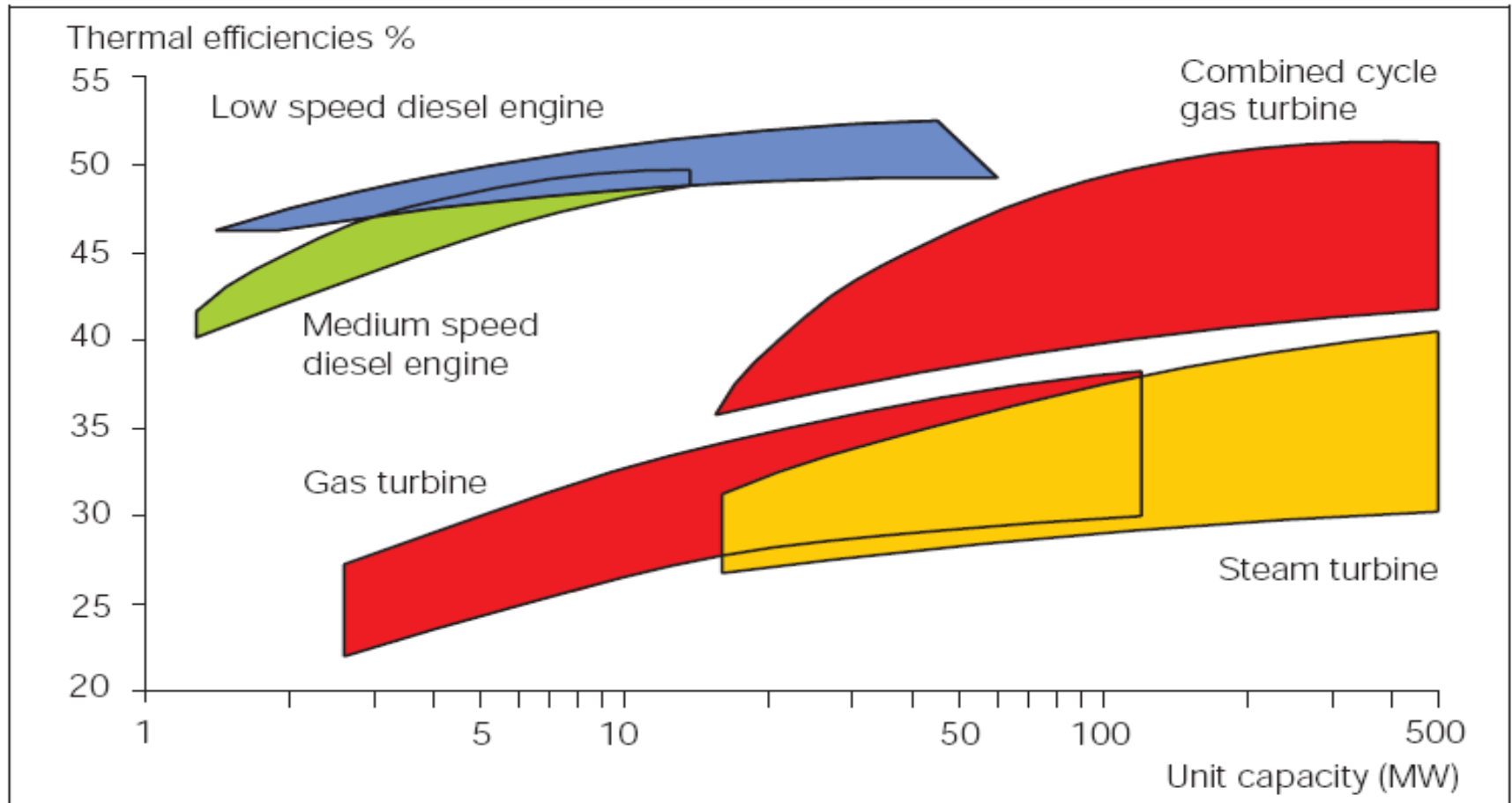
- Allows electric power generators to expand capacity incrementally (say in 50MW to 150MW steps) rather than in single huge steps (generally around 600MW to 900MW)
- Benefits in terms of land utilisation, waste materials generation, visibility and environmental impact
- Facilitates distributed power generation with significant cost and transmission line investment benefits
- Coal / Water fuels well researched.





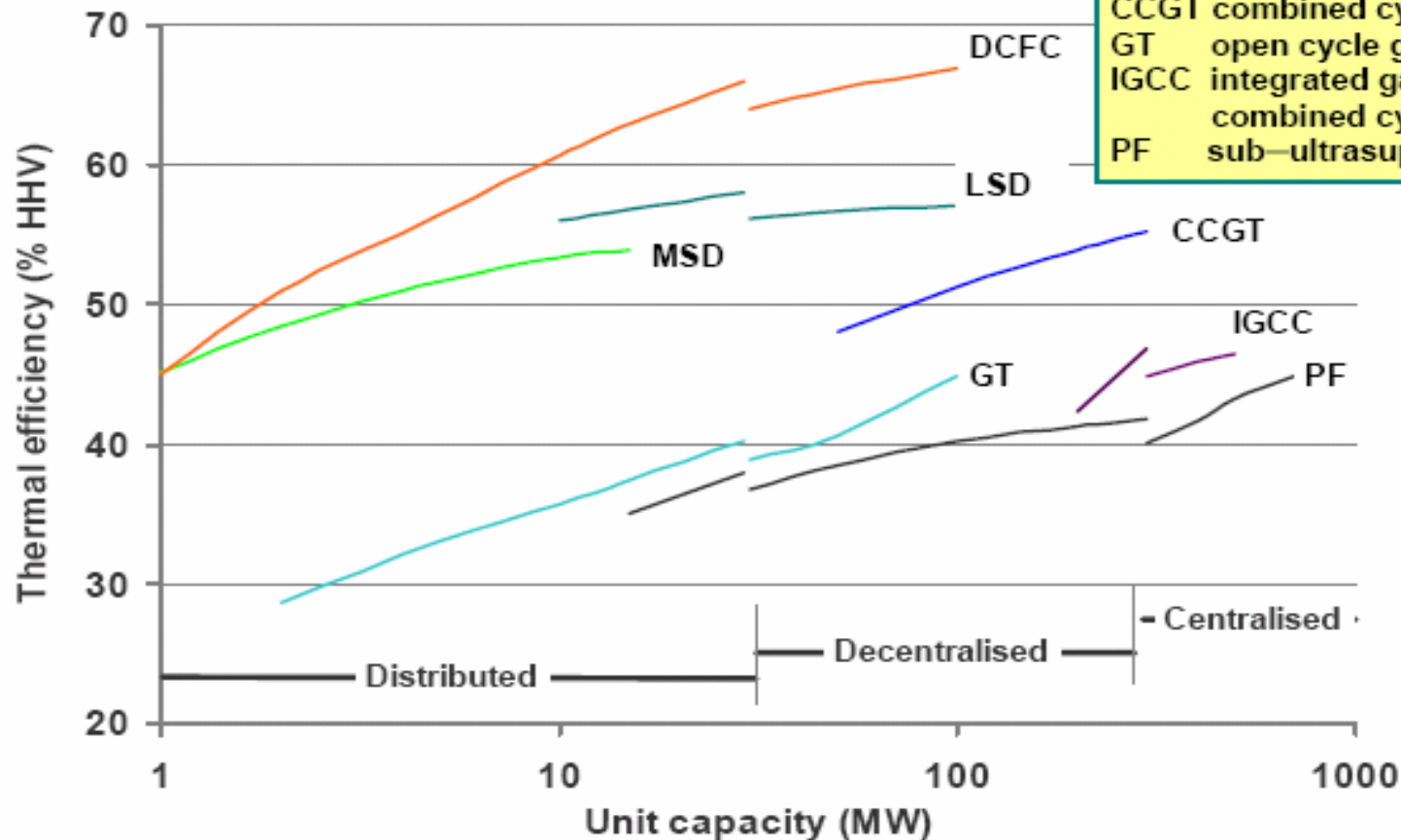
# UCC DIESEL APPLICATION – DICE

Efficiency comparisons (Source : MAN “Low Speed Engines in Stationary Diesel Power Plants”)



# LOW EMISSIONS THROUGH HIGH EFFICIENCY

DCFC direct carbon fuel cell  
LSD low speed diesel engine  
MSD med speed diesel engine  
CCGT combined cycle gas turbine  
GT open cycle gas turbine  
IGCC integrated gasification combined cycle  
PF sub-ultrasupercritical pf



# DIESEL - High Efficiency & Low Water Usage

	Unit	Current		Direct coal technologies		
		USC	IGCC	DFGT <sup>1</sup>	DICE <sup>2</sup>	DCFC <sup>3</sup>
Unit capacity	MWe	700	400	400	10-100	0.1-100
Coals		Most	<25% ash	ultra clean <0.2% ash	<2% ash	<0.2% ash
Efficiency sent out <sup>4</sup>	% HHV	42	43	48	51	65
Water	L/MWh	1800	600	600	250	in bottom cycle?
Flexibility		Med	Low	Med	High	High
Start-up time	h	8	8	5	<1	<1
Current status		mature	new	Lab & pilot	Pilot & demo	Lab

<sup>1</sup> Direct fired gas turbine <sup>2</sup> Direct injection coal engine <sup>3</sup> Direct coal fuel cell

<sup>4</sup> Includes fuel preparation



# UCC – Combined Cycle Gas Turbine

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- Suitable for use in large CCGT installations (say 300MW to 600MW)
- Lower fuel cost than natural gas with greater security of supply
- Lower capital cost than conventional coal-fired power or IGCC installations
- Greater generation efficiency and less GHG production than conventional coal fired power
- Gas turbine design modifications will be required for UCC firing
- A logical next step after large stationary engine (diesel) application of UCC
- Market segments to be captured:
  - new coal-fired power generation
  - new natural gas-fired CCGT power generation
  - re-fuelling existing CCGT installations



# UCC DEVELOPMENT PROGRAM

## Current Status

- **Currently recommissioning and expanding the UCC pilot plant.**
- **Committed 08/09 budget of \$9M for work program including production of 500t plus of UCC.**
- **Demonstration of UCC-fired Mid Speed Diesel Engine**
- **NSW Government announced the grant of ~70ha freehold + 80ha surrounding buffer on 2<sup>nd</sup> March 2007.**
- **Close to finalizing \$2M Research Grant from APP7 program.**
- **Preliminary Engineering & Utilization studies completed by WorleyParsons.**
- **Comissioning of Drying & Briquetting demonstration system currently underway. Committed budget \$9.3M (Grant \$4.3).**



# WAY FORWARD

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- UCC technology recognised within Coal 21 as player in the clean energy future
- The commercialisation plan is being advanced. The next step is to construct & operate a 30,000 t/y Demonstration Plant
  - Negotiating scope and cost for Engineering studies with Worley Parsons
  - Demonstrate viability of direct fired internal combustion engine concept with prominent engine supplier
  - Continue turbine testing with prominent turbine supplier
  - Raise Venture capital for continued commercialisation
- The first commercial plant will be 450,000 – 3 Mt/y capacity

**Attacking GHG through efficient utilisation of coal**



# **The End**

**G. F Yannoulis**

**August 2008**

