

**An IGCC Project at
Chinchilla, Australia
Based on
Underground Coal
Gasification (UCG)**



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INTRODUCTION

Underground Coal Gasification (UCG) is a process by which coal is converted in situ to a combustible gas that can be used as a fuel or chemical feedstock. The process has been used in commercial-size projects in the former Soviet Union for more than 40 years, while significant national research programs have been undertaken in the United States and Western Europe. So far UCG activities in the Western world have not resulted in a commercial development.

There now appear to be a combination of factors which give a new impetus to the commercialisation of the technology in Australia. These include the new competitiveness of the power industry, a desire to switch to gas as a fuel due to efficiencies in gas turbine combustion, and a reviving interest in synthetic fuels as a result of high oil prices. Linc Energy (as owner) and Ergo Exergy (as technology supplier) have combined to develop the first commercial IGCC project based on UCG. It is proposed that GE Power Systems provide their expertise in combustion of low calorific gas for the turbine design.

The project is located near the town of Chinchilla, some 350 km west of Brisbane, in Queensland, Australia. The project design consists of a UCG production facility, a gas processing plant, and the power generation block. Gas has been produced for 21 months, with final process design, plant selection and financing currently in progress, and an anticipated commissioning date at the end of 2002.

PROCESS SUMMARY

In its simplest form, the UCG process is initiated by drilling two adjacent boreholes into a coal seam (typically > 100m depth), and the injection of a pressurised oxidant such as air or oxygen/steam and subsequent down-hole ignition of the coal seam (refer Figure 1). The product gases from the gasification process are recovered from the second well. The gasification process is somewhat similar to that utilised in surface gasification plants, with the product gases being a mixture of hydrogen, carbon monoxide, methane, carbon dioxide, and higher hydrocarbons. Typical gas recovered using air injection may have calorific values in the range 3.5 to 5.0 MJ/m³, depending on specific site conditions, with approximately twice these values being achieved with oxygen injection. The initial gasification reactor can be readily expanded by drilling and connecting additional injection and production wells.

There are a number of site-specific technical factors which are important in using the process on a particular coal resource, such as the geology of the coal seam, overburden thickness and properties, and the hydrogeology of the coal seam and surrounding strata. While each of these factors is individually important, it is the overall appraisal of the many technical aspects of a site that governs its suitability. Commercial factors such as the size of the coal resource and the market for gas are also critical to project development.

UCG PRODUCTION PROCESS

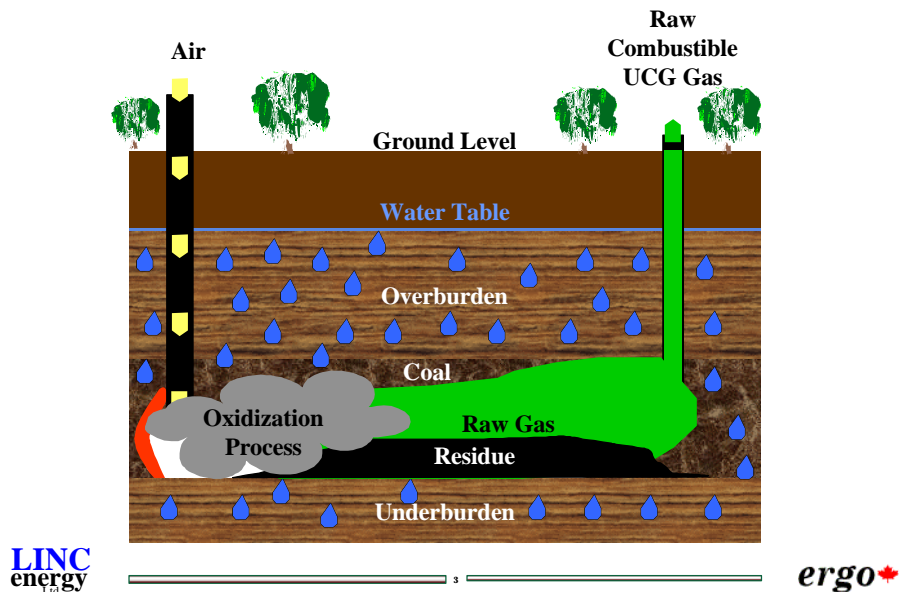


Figure 1

COMMERCIAL BENEFITS OF UCG-IGCC

The essential commercial features of the project which are perhaps unique for a coal-based IGCC facility can be summarised as follows:

Scale: The Chinchilla project is based around a GE Frame 6B gas turbine, with an estimated combined cycle output of 67MW_e (base load). Despite this small scale, the project shows commercial rates of return when competing in the grid against coal-fired power stations 10 times the size.

Subsidies: The project economics are based on receiving no Government subsidies or incentives of any kind.

Availability: Because of the nature of the process, a 100% availability of the gasifier can be achieved.

Competitiveness: The Chinchilla IGCC facility will be selling into a power market in which current prices are as low as US 1.5¢ per kWh. This is made possible by the low gas cost.

Gas Resource: In Queensland alone, Linc Energy has rights to coal which are estimated to be capable of supplying gas to generate 5000 MW_e of base load power for more than 300 years.

In addition to these features, the UCG process provides significant environmental benefits over coal-fired power plants. These include:

- Minimal surface disturbance from operations
- Increased worker safety
- No surface disposal of ash and coal tailings from coal washing plants
- Minimal site rehabilitation
- Reduced CO₂ emissions due to combined cycle efficiencies
- Potential to remove CO₂ from the product gas before combustion, sequester it in the coal seam, and further reduce emissions

To further illustrate the competitive Australian power market, Figure 2 shows the trend in spot electricity market over the past three years, leading to the projections early next year for a price of US 1.5¢ per kWh. This compares with a projected targeted cost for IGCC power using surface gasification of about US 4¢ per kWh. It is estimated in Australia that the cost of power produced from a new coal-fired plant would be in the range US 1.5 – 1.75¢ per kWh, while for a natural gas-fired plant at base load this cost would be in the range US 2.0 – 2.5¢ per kWh. These prices make it difficult to replace coal with natural gas as a fuel without significant power price increases, without even considering the limited gas resources on mainland Australia. It is in this commercial environment that UCG gas provides the benefits of using part of the country's vast coal resources, while producing a low-cost gas with subsequent greenhouse emission benefits.

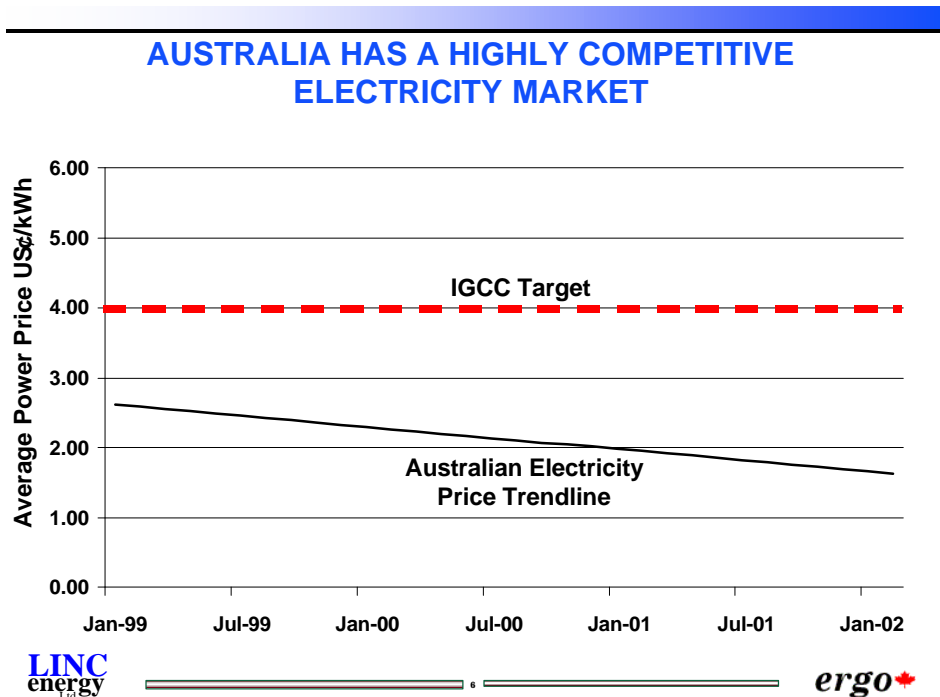


Figure 2

UCG IGCC HAS SIGNIFICANT ADVANTAGES

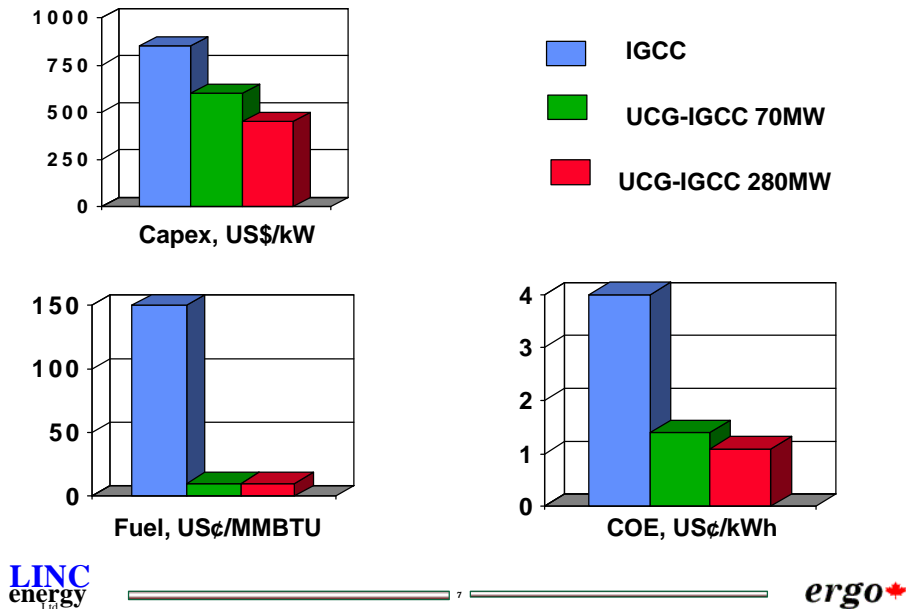


Figure 3

The financial advantages of UCG-IGCC when compared with surface gasification are summarised in Figure 3, using figures published in previous conferences for IGCC, and UCG-IGCC estimated for both 70MW_e and 280 MW_e. The capital costs for UCG clearly relate to the minimal surface facilities required for the operation, where the gasifier is defined by the coal seam and its confining layers. The fuel is effectively free, as the process uses deep coal unsuitable or uneconomic for conventional mining operations, the only cost being relevant government royalties. These two factors combine to produce the low cost of power generated.

PROJECT DEVELOPMENT

In June 1999, Linc Energy entered into a Joint Venture agreement with CS Energy, one of Queensland's power generators, to undertake a pilot burn on the Company's coal lease near Chinchilla, 350km west of Brisbane. Since that date, Linc Energy has undertaken a site characterisation program (August 1999), commenced a pilot burn using three process wells (26 December 1999), expanded to eight operating wells, and has now operated with continuous gas production for 21 months to the present date. This makes the operation by far the longest burn in the history of UCG development in the Western world, while confirming the low capital and operating costs of the process.

THE CHINCHILLA PROJECT SITE



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Figure 4

The operation is located on a farm property, and covers an area about 200m square (Figure 4) within a Mining Development Lease granted by the Queensland Government. This Lease covers an area about 1.5sq. km., and with its surrounding area, contains over 100 million tonnes of coal, sufficient to last this IGCC project for more than 200 years. Attached to this Lease is an Environmental Management Plan (EMP), which includes all relevant environmental issues to be addressed by the Company during its operations. In particular, the EMP requires the Company to undertake regular monitoring programs to cover aspects such as site surface disturbance, subsidence, groundwater impacts, noise, and air quality. The Company has regular independent audits made to confirm compliance with the EMP.

Since the commencement of operations, approximately 20,000 tonnes of coal have been gasified, and 55 million cub. metres of gas produced (Figure 5). Monthly production has steadily increased with the installation of additional wells (Figure 6), although each well has not been operated to its full capacity to minimise coal usage. For the same reason, production has been cut back since May this year as preparations are made for finalising the program for project development. This program anticipates commissioning of the gas turbine at the end of next year, and addition of the steam cycle 12 months later.

CHINCHILLA PROJECT CUMULATIVE PRODUCTION

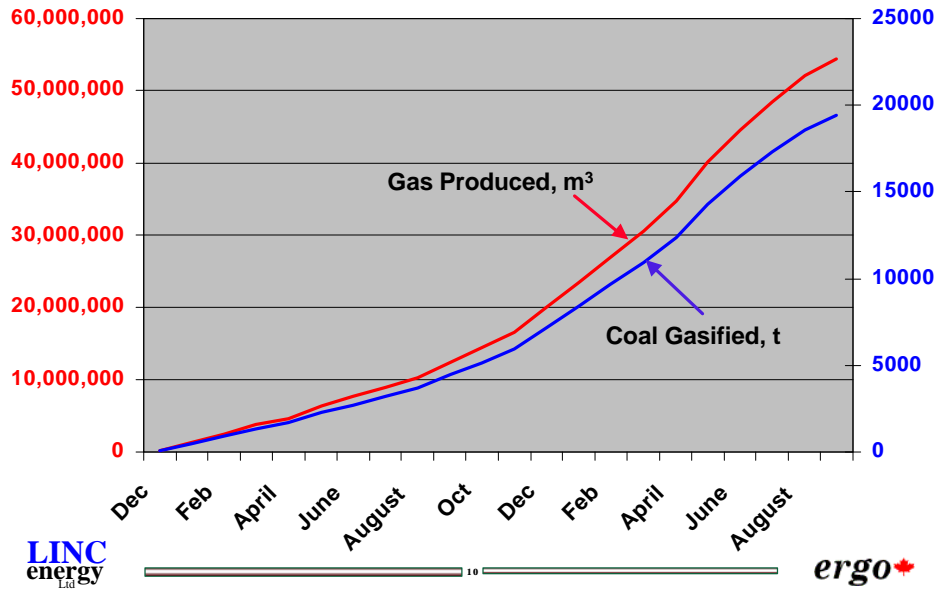


Figure 5

CHINCHILLA PROJECT MONTHLY PRODUCTION

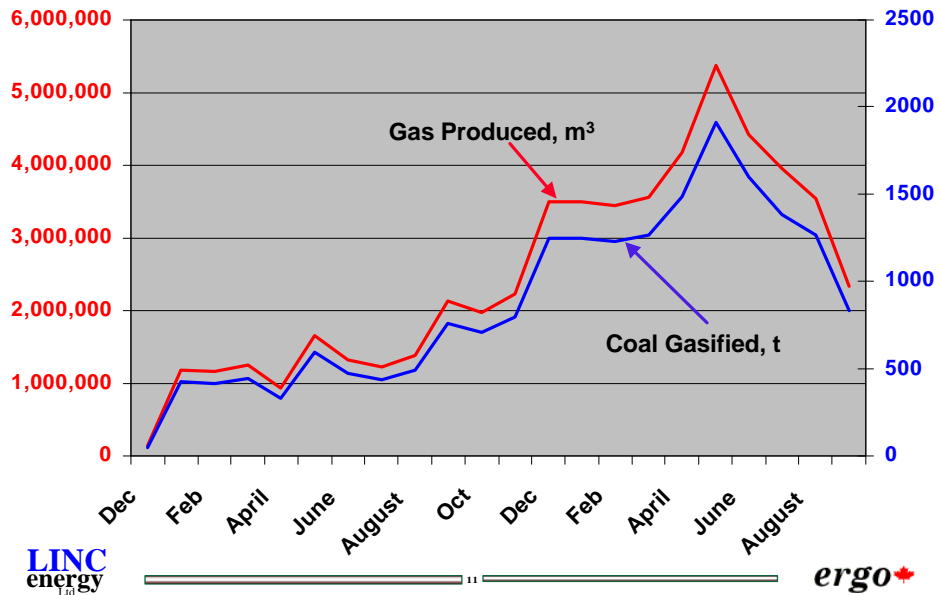


Figure 6

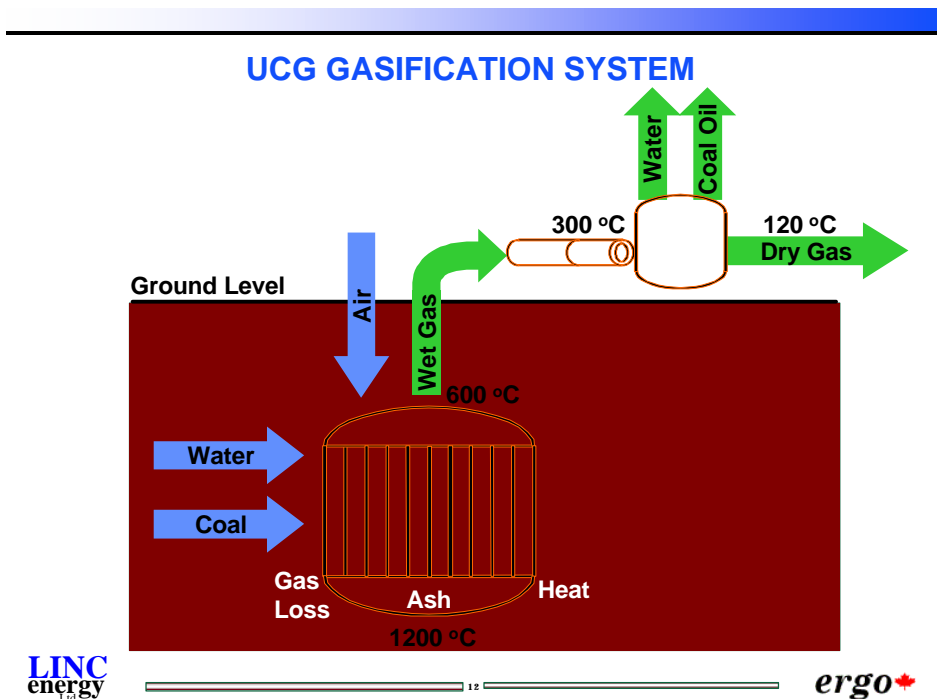


Figure 7

GASIFICATION PROCESS

Underground gasification differs from other gasification methods: it is performed in non-mined coal seams deep in the ground (refer Figure 7) rather than in the steel vessels of gasification plants. As a result, the sources of the process diagnostics and the means of direct operator's intervention are limited. Thorough knowledge of underground conditions must be used to design and build a commercial scale underground gasifier and to select operating regimes that ensure stable and consistent gas production.

Process parameters, such as operating pressure, outlet temperature and flow are governed by the coal and rock properties that vary with time and location. Information on the process conditions must be constantly monitored and updated as the gasifier develops. Process parameters should be adjusted accordingly to accommodate ever-variable conditions of gasification.

Advantages of operating a large underground gasifier include the following:

- A practically unlimited supply of coal is available for gasification, no coal and water supply is required to sustain the reaction.
- The UCG process creates an immense underground gas and heat storage capacity, which makes the gas supply very stable and robust.
- An underground gasifier is made up of a number of underground reactors with largely independent outputs. The gas streams from different reactors can be mixed as required to ensure consistency of overall gas quality. The outputs of reactors

can be varied in order to optimise coal extraction and gas supply from the whole gasifier.

- No ash or slag removal and handling are necessary since they stay behind in the underground cavities.
- Ground water influx into the gasifier creates an effective “steam jacket” around the reactor making the heat loss in situ tolerably small.
- Optimal pressure in the underground gasifier promotes ground water flow into the cavity, thus confining the chemical process to the limits of the gasifier and preventing contamination in the area.

The underground gasifier in Chinchilla covers an area of 200 x 300 m and may be part of a system of a number of underground gasifiers that can be operated simultaneously. It comprises a system of wells interconnected within a 10 m thick coal seam to form a complicated underground pattern at the depth of 140 m. It is designed to produce up to 155,000 Nm³/h of gas but will normally be operated at 63% capacity to supply gas for a 67 MWe combined cycle power plant. The design lifetime of the gasifier is 4.1 years.

The process uses coal of the following quality:

Table 1. **Proximate analysis**

Moisture %	6.8
Ash %	19.3
Volatile %	40.0
Fixed Carbon %	33.9
Total %	100.0
Total Moisture %	10.1
Relative Density	1.50
SE MJ/kg	23.00

Gas produced by the underground gasifier comes to the wellhead at 10.5 barg and 300°C. The choice of the gas pressure is limited by the permeability of coal and rocks, whereas the temperature is restricted to protect the mechanical integrity of production wells. The gas contains water and hydrocarbons, both water soluble and insoluble, and particulates. Tests show that to date the particulate load has been much lower than expected in modern gasification plants. Early tests have shown as little as 4 ppmw of particulates in the gas flow. Average water content was measured at about 17% vol/vol. The water stream contains commercially recoverable quantities of phenols and ammonia. The liquid hydrocarbons condensed from the gas have a calorific value of 40 MJ/kg and demonstrate physical properties similar to those of light crude oil.

The main challenges of the gasifier development included:

- Adaptation and optimisation of the well linking techniques
- Adjustment of drilling techniques and completion methods
- The necessity to operate the gasifier at minimal capacity to protect the resource while maintaining consistent quality of gas production

These challenges have been successfully met in Chinchilla. The site operates 8 wells, current coal throughput is limited at about 60 tonnes a day, all produced gas is flared, and liquid hydrocarbons are sold as fuel oil. It is planned to complete construction of the gas production facility in November 2003 when the rest of the project will be ready to receive the full production quantity of gas.

The 21 months of continuous and stable gas production in Chinchilla, in full compliance with environmental guidelines, industrial and health and safety regulations, has created a reliable basis for the design and construction of the full-scale gas facility as a part of the 67MWe IGCC project.

PLANT DESIGN

The gas turbine is the heart of an IGCC project. It is envisioned that the GT for the project will be supplied by General Electric.

GE pioneered syngas gas turbine technology nearly three decades ago and has developed a broad dedicated product line of gas and turbines and matching steam turbines ranging from 10 to 300 MW for syngas applications. Syngas gas turbines are proven products with a total of 34 GE IGCC units sold of which 22 have accumulated over 360,000 hours of operation on syngas.

Gas turbines for syngas applications have basic technical and functional requirements that are different from those of a gas turbine operating on natural gas. Therefore, gas turbines must be modified with features that allow for efficient and reliable syngas service. These syngas specific features relate primarily to the combustion and fuel systems but also include some special fire protection, packaging, and controls modifications.

The core of a syngas gas turbine design is based on combustion system adaptation through laboratory testing. Combustors must be designed for a wide range of operating conditions with primary syngas, backup fuel, and possible co-firing of both fuels. The multiple can-annular combustor design of GE gas turbines results in excellent flame stability and mixing properties that produce very low emissions. This design also makes it possible to burn multiple fuels, including distillate, naphtha, syngas, propane and methane.

Due to the steady operational requirements of the gasification, syngas power plants perform best in base load applications. Syngas gas turbines require natural gas or distillate as a start-up fuel; i.e., all syngas gas turbines must be dual fuel capable. Consequently, syngas power plants can switch to the backup fuel when syngas is unavailable or co-fire when syngas is limited. This increases the plant's power availability to levels equivalent to natural gas fuelled power plants.

Because of the low heating value of syngas when compared to natural gas, significantly more fuel is required in an IGCC turbine than a natural gas turbine. As a consequence, the mass-flow, and thus the output power, of the gas turbine is much higher for an IGCC application. For the same reason, the gas turbine's output power is flat-rated up to very high temperatures.

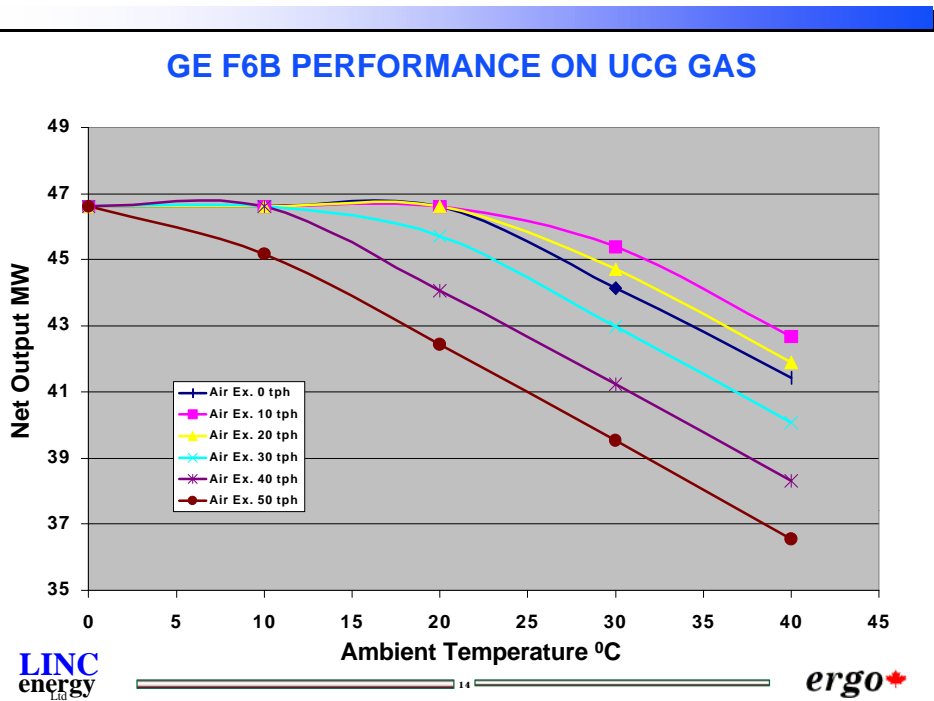


Figure 8

GE has evaluated the syngas produced by the underground coal gasification facility in Chinchilla and has determined that it is an acceptable fuel for GE's syngas frame 6B heavy duty industrial gas turbine. At average ambient conditions of 25 degrees Celsius, the frame 6B produces at least 45 MW of simple cycle output power.

Figure 8 demonstrates the performance of a frame 6B gas turbine on the Chinchilla site as a function of ambient temperature and air extraction. Optimal performance is reached with the air extraction at about 15 tonnes per hour. This air will be used as a part of total injection duty of the plant.

The plant flow diagram is illustrated in Figure 9. The process plant is used to condition the gas to satisfy strict requirements of the gas turbine. Raw gas produced at well head is cooled down to separate the liquids that are further processed and prepared for sale and disposal. The gas then is cleaned up in sintered metal candle filters. Since candle filters require dry gas for normal functioning, the gas is reheated to the temperatures above dew point before entering the filters. A pilot cleanup plant simulating conditions of the full-scale process is being tested on site.

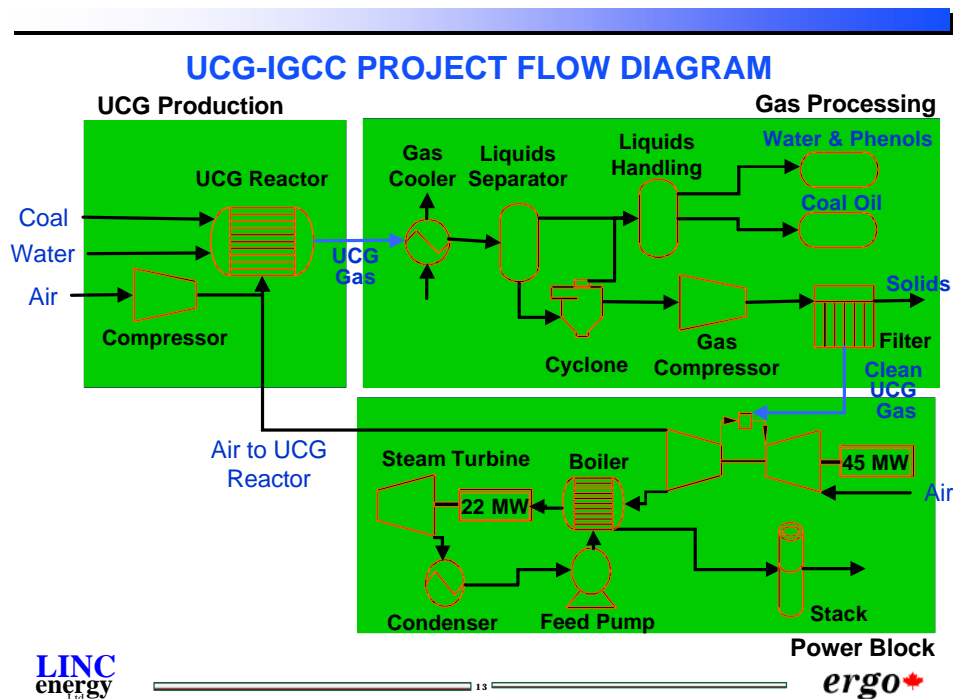


Figure 9

A gas compressor is required to bring the pressure of the gas to the level acceptable for the gas turbine. Water separated from the gas flow is used for cooling the raw gas in a heat exchanger and the air in air compressor intercoolers. It will comprise a part of water needed to operate the steam cycle once a steam turbine it is installed.

The degree of integration in a UCG-IGCC plant is limited compared to modern IGCC projects since UCG gas production is distributed over a considerable area, and it is problematic to attain full integration of energy streams between gasification and power islands due to the length and variability of the gas gathering pipelines.

PLANT OUTPUT

The Chinchilla UCG-IGCC project is by its nature a complex plant combining energy and chemical outputs. Its performance can be optimised to maximise power output or alternatively, production of chemicals received as by-products of gasification. The deeper is the cooling of the raw gas in the process plant, the greater is the chemical output of the plant. At the same time, the more liquids that are knocked out from the gas, the less is the gas flow rate through the gas turbine, which leads to a decrease in the power output of the plant. The UCG-IGCC plant in Chinchilla has been optimised to maximise power generation capacity. Although the high value of by-products may make it economically attractive to increase the chemical output at the expense of power generation, the principal objective of the project is to demonstrate efficient power generation based on UCG gas production. Once this task is accomplished, the plant outputs will be adjusted to achieve maximal commercial returns.

Fully developed, the Chinchilla project will realize the outputs presented in Figure 10. The hydrocarbons separated from the liquid stream in the process plant contain a number of highly valuable components. Further processing of chemical streams with extraction of high value products is a matter for the next stage of the plant development.

CHINCHILLA PROJECT OUTPUTS

Products	Output	Energy
Electricity		67 MW
Gas	800 Million Nm ³ /annum	4.4 PJ/annum
Hydrocarbons	15,000 tonnes/annum	0.6 PJ/annum
Phenols	3700 tonnes/annum	
Anhydrous NH₃	1500 tonnes/annum	
Clean Water	200 Megalitres/annum	

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Figure 10

The project is located in an arid area. There is a very limited amount of water available for industrial development and agriculture. Water produced by UCG-IGCC operations will find application both in the plant and neighbouring farms.

CONCLUSION

The main achievement of this project is to demonstrate that UCG can provide commercial quantities of industrial gas for power generation at a price that ensures the economic viability of a coal-based IGCC project in a competitive power market.

The UCG-IGCC project at Chinchilla is the first in a number of UCG based power generation and chemical projects that are in different stages of preparation and development in Australia and overseas. A number of applications, such as syntheses of ammonia and methanol, the Fisher-Tropsch process, ore reduction, etc. require gas that can be produced by UCG with enriched air and oxygen injection. Commencement of these trials is planned in the near future.

While UCG technology by its nature cannot completely replace other gasification methods, it provides an opportunity for early commercialisation of industrial projects, and the utilization of vast coal resources currently considered unusable.