Improving Coal Resource Utilisation – A New Zealand UCG Initiative

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Abstract

Underground Coal Gasification (UCG) is an emerging mining technology that has the potential to allow low cost access to energy from coal that is currently not technically or economically accessible by existing mining methods. As such it offers significant potential to dramatically increase the world's recoverable coal resources.

Between 2005 and 2012 Solid Energy investigated the potential of UCG to complement existing mining methods while facilitating access to un-minable coal resources. Pattle Delamore Partners (PDP) provided consenting and hydrogeological and environmental monitoring support throughout the project.

In order to manage the technical and commercial risks of applying UCG in the New Zealand geological and environmental setting, a staged gate project development approach was implemented. The first stage involving scoping and feasibility studies was completed between 2005 and 2008. This was followed by the second stage, a pilot plant, designed, constructed, operated, shutdown and rehabilitated near Huntly between 2009 and 2013.

This paper presents an overview of some of the UCG project development challenges faced and overcome in developing the Huntly UCG pilot plant, with emphasis on the identification and management of project-related risk. In particular the upfront geological, geotechnical, hydrogeological and environmental characterization and planning skills that are fundamental to a successful mineral sector development are discussed. The key pilot plant outcomes and authors' conclusions are presented along with implications for future development.

Keywords: UCG, coal, gasification, syngas, Waikato, pilot.

Introduction

Underground Coal Gasification (UCG) has the potential to create a modern day Maui gas field equivalent. The Waikato coalfields are estimated to contain over 1 billion tonnes of coal below 300m in depth (Kirk et al 1988), representing a potential UCG resource equivalent to five Maui gas fields. In addition to the Waikato other New Zealand coalfields are also suitable for UCG (Carr, 1987).

Government interest in UCG began as early as 1984 when the Ministry of Energy highlighted the need to find a way of economically recovering Waikato coal resources lying at depths greater that 200m and identified UCG and longwall mining as possibilities (Wylde, 1984). In 1985 the Ministry of Energy commissioned an American-based UCG company, Energy International, to evaluate the economics of producing UCG syngas from the Maramarua coalfield (Ministry of Energy, 1985). UCG figured prominently as a potential option in energy-future scenario modelling in 1986 (Boshier et al, 1986). When discussing the potential loss of Maui gas supplies it was suggested that "… (the) most straightforward … way to replace Maui gas when it is depleted would be to import LNG… other options include the in-situ gasification of deep Waikato Coal." An assessment of the New Zealand potential of UCG was then carried out in 1987 (Carr, 1987).

Commercial investigations into UCG development began in 1988 with the Electricity Corporation of New Zealand (ECNZ) funding a pre-feasibility study by Venture Pacific and Energy International into the possibility of developing UCG as a fuel source for Huntly Power Station. In 1990 three coal prospecting licences were granted to Venture Pacific for the purpose of investigating the viability of UCG at Huntly and Maramarua.

1992 saw ECNZ, Glencoal Energy and Energy International form a joint venture to investigate the feasibility of a UCG development north of the Huntly Power Station. It is understood by the authors that the rationale was to assess the viability of UCG as an alternative gas supply to the Maui gas field which, at that time, dominated New Zealand's natural gas supply and its output was forecast to begin declining in the early 2000's. Fieldwork and other investigations were carried out over the next couple of years cumulating in a small (12 day) UCG test burn which took place in late 1994.

In 2003, after investigations confirmed initial technical viability of the technology, Solid Energy began a risk-managed, staged development of a UCG project to quantify the risks and benefits of applying this technology on a commercial scale.

Deep Un-minable Coal – A Huge Energy Resource

Of the known non-renewable energy resources globally, coal, due to its established size and geographical distribution, will inevitably play a major role in meeting the increased energy demands in the future (World Coal Association 2012a). Coal resources are around 17 times larger than coal reserves and account for over two thirds of all non-renewable energy sources, including conventional and non-conventional hydrocarbons, such as oil and gas (World Coal Association 2012b). Coal is the world's most abundant non-renewable energy fuel.

Continued and increasing coal use has challenges; increasing resource depth, thinner multi-seam environments, contribution to Green House Gas (GHG) emissions and environmental impacts (air, land use, water). Potential technologies being considered internationally to increase resource access while addressing some or all of these challenges include improved underground mining methods (long-wall mining, hydraulic mining), Coal Seam Gas (CSG), Microbial coal conversion (MCC) and Underground Coal Gasification (UCG).

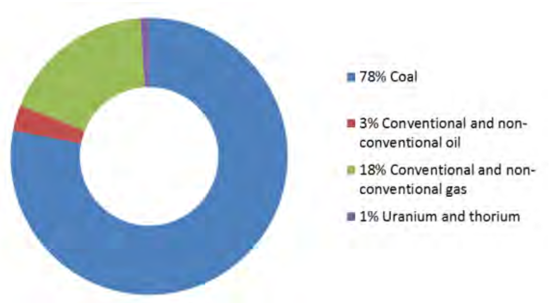

Figure 1. Non-renewable energy resources (World Coal Association 2012b)

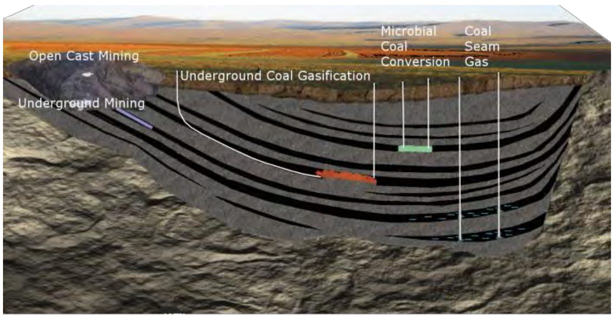

Figure 2. Coal resource utilisation technologies (Puri 2014)

New Zealand has significant indigenous coal resources. Estimated in-ground resources of all New Zealand coals exceed 15 billion tonnes (MBIE 2013) with the majority being comprised of shallow lignite.

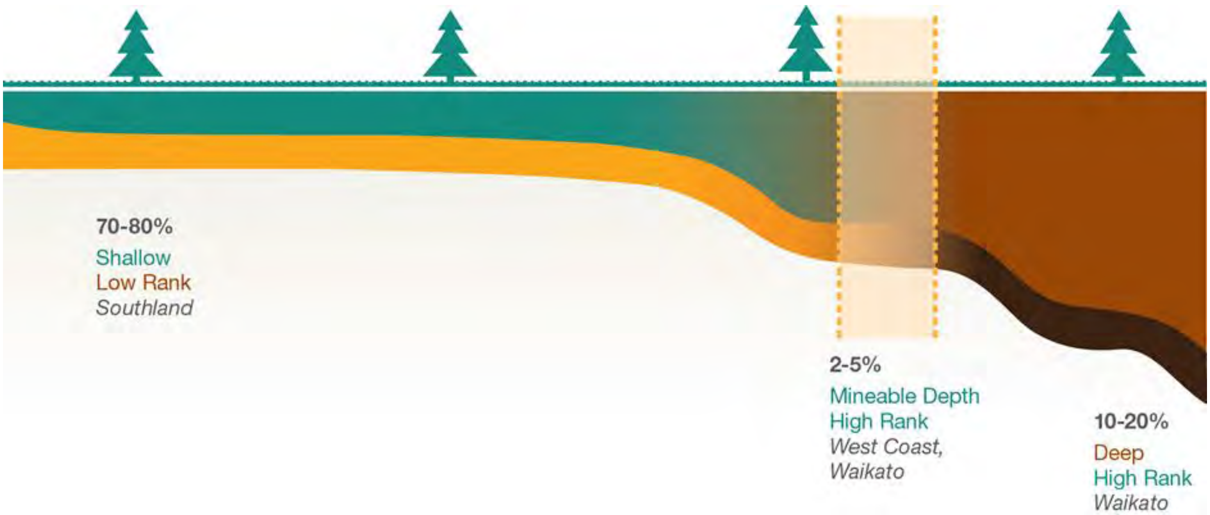

Figure 3. New Zealand's coal resource profile

Coal mining in New Zealand has, to date, largely focussed on the small portion of coal resource that is both high enough rank to justify transport to market and that lies at an economically mineable depth. Much of this easily accessed, high value coal has been mined over the past 150 years and coal is becoming increasingly difficult and costly to access and transport to market.

Underground Coal Gasification (UCG)

Underground Coal Gasification (UCG) is potentially a global technology breakthrough. It is a mining method that is both an extraction process (like mining) and a conversion process (gasification) in one step. It eliminates the need for mining, coal handling equipment and gasification reactors by reacting the coal underground with an oxidant to produce a manufactured synthetic gas. UCG has the potential to unlock un-mineable coal resources. Estimates of potential additional reserves accessible by UCG technology are 400–900 billion tonnes, doubling current global recoverable coal reserves (World Energy Council, 2007).

UCG offers a number of advantages compared to conventional mining (LLNL, 2004):

- Applicability to a wide range of coal resources
- Improved health and safety
- Increased product versatility
- Improved environmental performance
- Lower cost

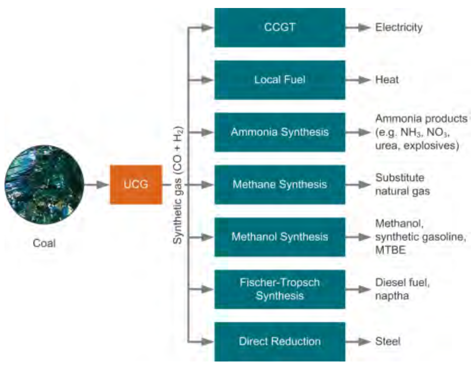

Figure 4. Increased product versatility

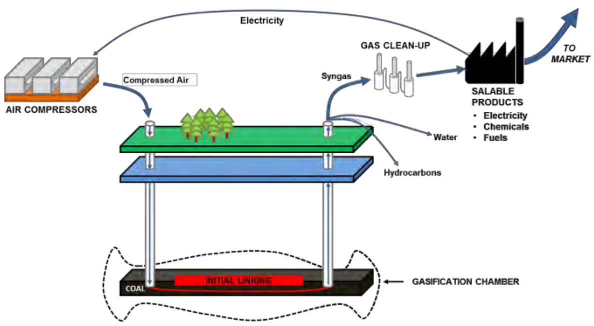

Figure 5. Generalised process schematic

Project Rationale

In this project UCG offered the opportunity to develop a new coal mining technique that potentially:

- would utilise core coal mining technical competencies,
- allows access to significant un-mineable coal resource,
- could be implemented at significant scale,
- added to existing mining operations (not replacing),
- opened up new markets not currently accessible by lump coal, and
- produced energy at a lower cost than currently achievable through conventional mining operations.

Due to the increased global interest in the benefits that UCG could bring and the relatively small pool of experienced project developers globally, the international potential for leveraging the capability that would be built within a New Zealand project was also recognised.

In addition to the advantages above, the cost of natural gas in New Zealand was being forecast to rise as the Maui gas fields production declined and as new gas fields were developed and bought into production.

A decision was made to investigate UCG as a new mining initiative alongside other conventional mining opportunities available at the time.

A Risk-Managed Project Development Approach

The commercial implementation of any new technology is always fraught with risk and any project involving geology more so.

In order to manage risks associated with the development of projects Solid Energy at that time utilised a staged gate project development approach similar to that found in any large company. As uncertainty decreases with each stage being complete, expenditure is allowed to increase. For reasons outlined below it was decided that operation of a pilot plant was a critical risk mitigation step in the development of a commercial facility; thus the UCG project gates were as follows.

Figure 6. UCG project staged gates

The scoping study phase of the project identified four key interrelated areas of risk that required management as the project was developed:

- Technical risks
- Environmental risks
- Commercial risks
- Stakeholder risks

An overview of how each of these risk areas was managed is described below.

Technical Risks

The UCG project technical risk fell into two main categories: technology and resource.

Technology

Technology risk was addressed in multiple ways: building a project team with the correct knowledge and experience; aligning with a technology provider; establishing working relationships with current international UCG project developers; building a comprehensive technical library of previous international projects; engaging with those involved in the previous Waikato based UCG trial; using specialist consultants; and, involving the company's conventional mining technical staff who had an intimate working knowledge of the Waikato coal geology.

Having the right project team is critical to the successful development and implementation of any project. A dedicated team was selected which comprised a core of individuals with a track record of developing and implementing energy-related technologies. Further team members were added with specialist skills in project management, technical documentation, business process development and engineering geology. Key to the success of this team was the shared culture of excellence, open honest communication and being genuine team players.

Ergo Exergy Technologies Inc. (EETI) of Montreal, Canada was selected as the most credible UCG technology provider in the market at that time. EETI's technology is based on the extensive Russian expertise with experts on the team holding 40 – 50 years of UCG experience. At the time EETI was also the only technology provider with a proven track record for development and operation of recent UCG pilot sites (both in Australia and South Africa). EETI had been developing a project in South Africa since 2001 with state-owned electricity generator Eskom at Majuba, southeast of Johannesburg. Eskom was contacted and visited several times over the course of the project which was invaluable for sharing experiences and capturing lessons learned.

Building a comprehensive technical library of previous UCG investigations resulted in a project team that were well aware of the key challenges that had been faced elsewhere and how they had been dealt with. This resulted in all project assumptions and risks being critically evaluated and, where necessary, challenged, leading to designs and operational plans that eliminated risk where possible and managed the remaining residual risks.

A number of key personnel involved in the 1994 trial were contacted which ensured that the lessons learned from that trial were captured and incorporated in areas ranging from project management, geology and environmental monitoring to equipment selection.

The project team was supported by a range of specialist consultants who added considerable value in their particular areas of expertise, to include hydrogeology, geomechanics, health and safety and process engineering detailed design. Each consultant "bought into" the project and its objectives and contributed significantly to its success.

The company's underground technical mining team provided invaluable technical advice on coal seam conditions and in particular inferring ground conditions from borehole and 3D seismic survey data. The close proximity of Huntly East mine to the UCG pilot plant site provided unique opportunities for "field trips" to view first-hand conditions in the coal seam and provided significant insight as to how the coal seam would behave under UCG process conditions.

Resource

Resource risk was addressed systematically beginning at a general level and becoming increasingly focussed as the project matured. Preliminary analysis confirmed that UCG technology was likely to be applicable to multiple sites in New Zealand (North and South Island). Further work carried out focussed on determining the most suitable of these coal resources on which to develop a UCG facility. It was concluded that the Huntly West sector of the Huntly coalfield was technically and environmentally preferred as well as being strategically located with respect to potential markets.

It was decided to locate the UCG initial development at the western edge of the Huntly West sector in order not to sterilise any resource potentially accessible by the Huntly East underground coal mine.

In order to reduce the resource risk posed by the proximity to the edge of the coalfield, four coal exploration holes were drilled to confirm coal presence and thickness. Once coal presence and adequate thickness were confirmed a 3D seismic survey was undertaken to confirm both the coal seam geometry and the size and location of faults to enable optimum pilot plant location.

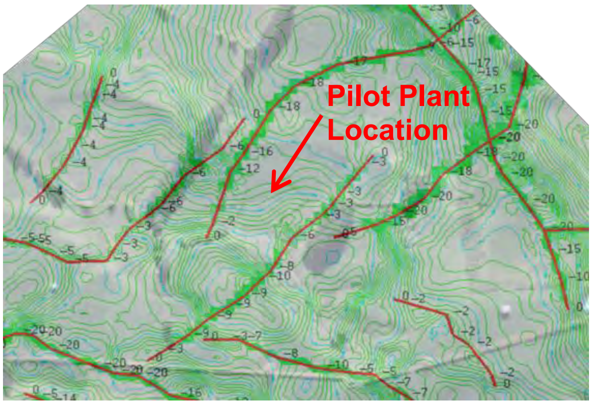

Figure 7. Seismic survey showing faults and top of coal

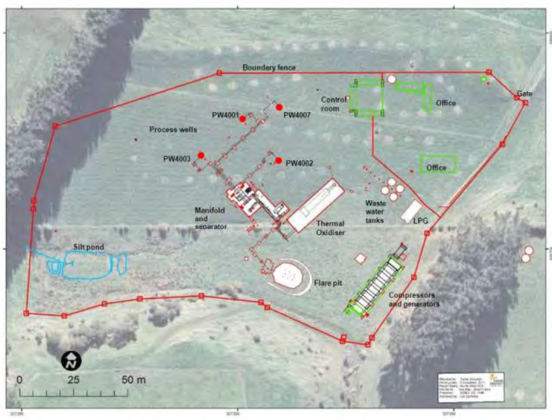

Figure 8. Pilot site layout including surface plant

Further UCG specific characterisation of the site was carried out via injection testing utilising both liquid and nitrogen/air followed by detailed analysis of the resultant pressure data. This analysis, in addition to numerical modelling, allowed the impact of process air injection to be assessed and operating parameters estimated.

Environmental Risks

Confidence in the ability to be able to carry out the UCG process in an environmentally acceptable manner is a key criterion for being able to gain commercial facility resource consents.

While there were a number of international examples of UCG trials being conducted in an acceptable manner there were also a small number of well publicised examples where the environmental performance was less than desirable. In each of these cases the underlying causes of the environmental problems had been identified and thoroughly investigated, and are able to be mitigated. The importance and value of being able to demonstrate that the entire UCG technology lifecycle can be carried out at a pilot scale in an environmentally acceptable manner was recognised as both essential to the eventual consenting of a commercial plant and to gaining widespread stakeholder support.

Because you only get one opportunity to collect data from pilot plant operations, considerable emphasis was placed on the design of both the environmental monitoring system and the quality assurance / quality checking procedures. This ensured that at the conclusion of the trial sufficient data had been collected to enable the environmental performance of the plant to be characterised.

Commercial Risks

Commercial risks associated with a commercial UCG facility development were managed through the staged gate project development framework where expenditure was only allowed to increase as key project risks were eliminated or managed.

The design, construction and operation of the pilot plant itself provided valuable substantiation of the assumptions in the techno-economic model which formed the basis for the commercial UCG facility business case.

Stakeholder Risks

A key success factor of any new development is having the confidence and support of a wide range of stakeholder groups. At the outset the project team adopted an approach which focussed on early engagement with all project stakeholders both internal to the company and external, which required open and frequent communication throughout the project. This allowed genuine consultation to occur and for the concerns of each group to be either alleviated immediately or incorporated into the pilot plant project to be addressed as the project progressed.

An especially important stakeholder group to the project were the landowners and all adjoining neighbours. All neighbours were visited individually as soon as the project location was confirmed and invited to a BBQ onsite which became a regular six-monthly occurrence. The onsite BBQ's were a great opportunity to get up close to drilling rigs when on site, talk to staff and get first-hand information on pilot plant plans and progress. It was a great forum to discuss potential risks and how they were being addressed in a relatively informal setting. Having a well-informed local community proved invaluable later in the project as they were unmoved by negative media coverage of international UCG projects and remained very supportive of the Huntly project.

The project team had a policy of informing all stakeholders of any negative project-related news, how it impacted the project and how it was being addressed before it reached them through the media or other channels. This further strengthened trust in the project as it was obvious that challenges were not being hidden and that project stakeholders were being supplied with all relevant information.

Pilot Plant Aims and Objectives

The aims and objectives of the Pilot Plant were as follows:

- Demonstrate UCG technology capability through successful light up, gasification of coal and shut down of the pilot plant – a full operational life cycle
- Demonstrate project credibility and capability
- Build experience in the handling of gas and water treatment for the design of a large scale plant

- Demonstrate the operational and post-operation environmental credentials of UCG
- Build credibility with key stakeholders; internal; community; potential partners; regulators; and, government to support consenting and project development at next stage
- Build UCG technical understanding within the wider company
- Gather geotechnical and hydro-geological data and refine models in order to support mine planning and consenting of future development phases
- Design, construct and operate the pilot plant to best practice health and safety requirements

Figure 9. General view of the Huntly UCG pilot site

Pilot Plant Outcomes

The project successfully and safely demonstrated the application of UCG to the Huntly West coal resource producing syngas over a period of six months between April and September 2012.

All major project objectives were achieved:

Health & Safety

From the start of the project the intention had been to operate to global best practice health and safety requirements at all times. The preparation and acceptance of an externally reviewed safety case, and the successful completion of a Department of Labour facility inspection were proof of this commitment. Including site characterisation and construction, over 1,500 days were completed on the project with zero Lost Time Injuries (LTI's).

Technical

Key insights regarding the application of UCG in the Huntly West coalfield were gained, in particular those surrounding the management of groundwater inflow and linking methodology. Significant volumes of geotechnical and hydrogeological data have been gathered and models developed to support any future commercial UCG mine planning, consenting and evaluation of effects of future development phases.

Figure 10. Syngas burning in the Huntly UCG flare pit shortly after ignition

Environmental

Extensive data gathering established a robust baseline of ground water quality parameters in multiple horizons. With operation of the gasifier below hydrostatic pressure, the operational environmental credentials of UCG have been conclusively demonstrated. Gasification related effects during operation have been shown to be confined to the gasifier itself. No far field changes in ground water quality were observed.

Post operation the project has demonstrated the rapid decay of residual products in the gasifier cavity toward baseline and a management methodology for maintaining these conditions.

Commercial

The company built a world-leading UCG capability, both technically and operationally. The project team gained a sound understanding of UCG methods and techniques and how these will be applied to a future commercial plant.

Financial modelling assumptions associated with earlier analysis of a Huntly commercial project were refined; no show-stopper risks were identified and Pattle Delamore Partners believes the commercial case for UCG in Huntly West remains strong.

Stakeholder

Stakeholder management has been a focus of the project. Successful relationships were built at all levels: regulators, consenting authorities, Tangata Whenua (Tainui and Waahi Whaanui Trust), landowners and neighbours. With continuous and regular engagement the project progressively built credibility with both internal and external stakeholders.

Project Development Lessons Learned

Reflecting on the experience gained by the project team in delivering the Huntly UCG project there are a number of key lessons learned that have applicability for resource development projects in general, not just future UCG developments.

- Building a project team with appropriate skills and experience supported as required by external specialists is critical. Equally important is the development and maintenance of a team culture that values learning, technical excellence, continual improvement, open honest communication and being genuine team players
- Setting clear expectations on objectives and deliverables and all parties buying into these
- Giving the project team not only responsibility and accountability for delivering a project but also the required authority
- Early engagement, consultation and education of all stakeholder groups is invaluable. Inevitably people fill information vacuums with misinformation that is often more damaging than what is actually planned
- The importance of gathering robust baseline monitoring data to ensure that project impact can be unambiguously demonstrated especially in environments with high natural variability
- Risk identification and management is critical as is the willingness of all project team members to have honest and open discussions on risk issues

Implications for Future UCG Developments

The experience gained from the design and operation of the Huntly UCG pilot plant has, in the opinion of the authors, led to some broad conclusions and recommendations for any future UCG operations:

- UCG is a feasible technology for the extraction of deep-unmineable coal and offers a potential future option for utilisation of deep Waikato coal
- Reverse Combustion Linking (RCL) and hydraulic linking do not provide reliable, robust, cost effective links between process wells at a known position in the coal seam
- Horizontal drilling to pre-form links, providing positive link position control, maximum linking distance, and minimise damage to coal structure should be used
- Pressures throughout the gasifier should be maintained lower than, but close to, the baseline hydrostatic pressure. This would have the dual benefits of decreasing water influx and reducing the commercial plant risk associated with large scale de-watering and loss of saturation in the strata around the gasifier while providing environmental protection
- A holistic water management strategy is critical to successful deployment of the UCG technology. This is likely to include de-watering wells outside the immediate gasifier, recycling of produced water and comprehensive water pressure monitoring of the surrounding stratigraphy.

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