

Impact case study (REF3b)

<p>Institution: Imperial College London</p>
<p>Unit of Assessment: 12 Aeronautical, Mechanical, Chemical and Manufacturing Engineering</p>
<p>Title of case study: 10. A novel linear gasifier panel design for underground coal gasification (UCG) under weak roof rock conditions</p>
<p>1. Summary of the impact (indicative maximum 100 words)</p> <p>A US\$1.5 billion clean coal project at the YiHe Coal Field in Inner Mongolia was established in June 2011 as a joint venture between UK based Seamwell International Ltd and the state-owned China Energy Conservation and Environmental Protection Group. This is the first commercial project to employ the novel "Linear UCG Gasifier" design developed specifically for use under extremely weak underground roof conditions by Durucan, Korre and Shi at Imperial College London. Underground gasification under such conditions is made possible solely because of the novel gasifier design, which has opened up the potential to transform over 720 million tonnes of coal resource, that would otherwise have remained trapped, as a clean coal energy source for the next 20 years.</p>
<p>2. Underpinning research (indicative maximum 500 words)</p> <p>The Minerals, Energy and Environmental Engineering Research Group (MERG), led by Prof Sevket Durucan and Dr Anna Korre at Imperial College, carries out fundamental underpinning research into clean coal and energy technologies providing significant benefits to the economy, the environment, public policy and services, and hence to society in general.</p> <p>Power generation through Underground Coal Gasification (UCG) is less carbon-intensive and represents up to 20% saving on the CO₂ emissions of a traditional coal-fired power station. Furthermore, if the carbon capture and storage (CCS) technology is utilised, the saving can reach up to a 50% CO₂ on a traditional plant without capture. However, the UCG industry faces a major operational challenge as a significant proportion of the relatively low rank coal resource identified as targets for UCG in the coalfields of Inner Mongolia, India, Pakistan, Russia and a number of other coalfields of the world suffer from extremely weak roof rock conditions. Conventional UCG panel designs involve a period of sustained and unsupported <i>in situ</i> cavity growth process underground. This requires relatively competent roof rock conditions in order to maintain the linkage between the reagent injector and syngas producer wells. When working under extremely weak and unstable roof rock conditions, the cavity tends to collapse immediately and the linkage (production) is lost, making the UCG process impossible.</p> <p>Drawing upon their expertise in a number of disciplines, including geology, geomechanics, thermomechanics, coalbed methane reservoir geomechanics [1] and coal mine strata control, Professor Sevket Durucan (Imperial, 1988 - present), Dr Anna Korre (Imperial, 1996 – present) and Dr Ji-Quan Shi (Imperial, 1990 - present) addressed this challenge and developed the new "linear UCG gasifier" panel design during the REF period.</p> <p>The authors' research in clean coal and energy technologies dates back to two major projects on coalbed methane technology funded by the UK Department of Trade and Industry [2] and EPSRC [3] in November 1993 and March 1994 respectively. Experimental and numerical research carried out over the years focused on the implementation, for the first time, of geomechanics principles in coal and coalbed methane reservoir engineering and developed Imperial College's in-house enhanced coalbed methane simulators METSIM and METSIM2. Research led to the internationally recognised and adopted "Shi and Durucan Permeability Model" [4].</p> <p>From 2000 onwards, the Group's research was extended to incorporate underground coal gasification (UCG) and CO₂ storage technology in coalbeds [5], as well as saline aquifers and depleted gas reservoirs. Research grants and contracts secured during this period raised over £4.7m worth of funding from government agencies, Research Councils, industry and the European</p>

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Commission.

One such project with particular relevance to the impact case study presented here was carried out as part of a large EU FP6 contract [EU FP6 Grant SES6-CT-2004-502816, 2004-09] - and aimed at coupling underground coal gasification with CCS. Drawing upon their expertise in coal mining, CO₂ geological storage and CBM/ECBM reservoir geomechanics, the Group at Imperial introduced a novel approach to Underground Coal Gasification, integrating this technology with Carbon Capture and Storage (CCS) for field applications and issued a confidential report entitled "An investigation into the fundamental processes governing CO₂ storage in virgin seams and in coal seams stimulated by underground coal gasification" in 2009 [6]. The geomechanics of conventional UCG panel progression and the mechanisms of rock and roof failure around a UCG cavity were investigated and used as the means to simulate the permeability of coal seams in order to overcome the injectivity losses experienced during CO₂ storage in coal. The research attracted a number of approaches from companies seeking to implement these findings in the field.

Contracted by Seamwell International, a private UK natural energy resources company, in 2009 the Group's research on UCG focused on developing new UCG panel designs to ensure that the application of UCG technology can be extended to coalfields with weak roof conditions, such as those experienced in Inner Mongolia and elsewhere in the world. By combining the group's coal mine roof control expertise with extensive geomechanical and thermomechanical modelling, they were able to address the extremely weak roof challenge. They developed the new "linear UCG gasifier" panel design, utilising the relatively high mechanical strength of coal seams in the overall design, thereby enhancing roof rock stability and providing self-supporting UCG cavity growth and reagent injection/syngas production paths in the subsurface.

Research and monitoring of the performance of the "linear UCG gasifier" in the field will continue in collaboration with Seamwell International, Central Mining Institute (GIG) in Poland, CSIRO in Australia, Golder Associates in South Africa and a number of academic and industry partners within the context of a newly funded €4 million EU project coordinated by Imperial College during 2013-16 (FP7 Energy Project 608517, Technology Options for Coupled Underground Coal Gasification and CO₂ Capture and Storage, http://cordis.europa.eu/projects/rcn/109590_en.html or <https://www.imperial.ac.uk/ref/webarchive/gwf>).

3. References to the research (indicative maximum of six references)

* References that best indicate quality of underpinning research.

*[1] J.Q. Shi, S. Durucan, I.C. Sinka, "Key parameters controlling coalbed methane cavity well performance", *Int. Journal of Coal Geology*, Elsevier, Vol 49, pp.19-31, (2002) ISSN:0166-5162 DOI: [http://dx.doi.org/10.1016/S0166-5162\(01\)00054-4](http://dx.doi.org/10.1016/S0166-5162(01)00054-4);

[2] DTI Grant: O 22/6/3

Title: An experimental and theoretical investigation into coalbed methane well performance prediction and stimulation modelling

Principal Investigator: Durucan, Professor S, Department of Earth Science and Engineering, Imperial College London, Starts: 15 November 1993 Ends: 14 November 1996 Value (£): £305,000

[3] EPSRC Grant: GR/J85714/01 Standard Research

Title: Coalbed methane well stimulation-modelling and performance prediction

Principal Investigator: Durucan, Professor S, Department of Earth Science and Engineering, Imperial College London, Starts: 01 March 1994 Ends: 28 February 1997 Value (£): 166,957 (Pre-FEC)

* [4] J.Q. Shi, S. Durucan, "Drawdown induced changes in permeability of coalbeds: A new interpretation of the reservoir response to primary recovery", *Transport in Porous Media*, Kluwer Academic Publishers, Vol 56, pp.1-16, (Jul 2004) ISSN:0169-3913 DOI: <http://dx.doi.org/10.1023/B:TIPM.0000018398.19928.5a>

* [5] A. Korre, J.Q. Shi, C.C. Imrie Grattoni, S. Durucan, "Coalbed methane reservoir data and simulator parameter uncertainty modelling for CO₂ storage performance assessment", International Journal of Greenhouse Gas Control, Elsevier, Volume 1, Issue 4, pp. 492-501 (Oct 2007) ISSN:1750-5836 DOI: [http://dx.doi.org/10.1016/S1750-5836\(07\)00093-X](http://dx.doi.org/10.1016/S1750-5836(07)00093-X);

[6] "An investigation into the fundamental processes governing CO₂ storage in virgin seams and in coal seams stimulated by underground coal gasification", Confidential Report issued within the EU FP7 project SES6-2004-CT-502816, (2009)

4. Details of the impact (indicative maximum 750 words)

A recent report issued by Visiongain [7] in October 2012 predicts that the global underground coal gasification market will reach a value of \$570m in 2012; however, the successful exploitation of this resource in areas of unfavourable roof conditions will require the application of new and innovative panel designs. In particular Inner Mongolia has 770 billion tonnes of mostly low grade coal resource suitable for UCG. These coalfields are targeted by a number of international energy companies active in the field of underground coal gasification. However, the majority of the coal in these fields lies below several hundred metres of very weak (~1-2 MPa Unconfined Compressive Strength) sediments of Late Mesozoic sand, silt and conglomerate, rendering roof control extremely difficult, if not impossible, with the currently applied conventional UCG panel designs.

The "linear UCG gasifier" provides a viable solution to this engineering problem. Due to its commercially confidential nature, the details of the new "linear gasifier design" are not in the public domain. However, confidential reports from projects [8] and those written for Seamwell International and the China Energy Conservation and Environmental Protection Group [9] confirm the new linear UCG gasifier as a viable solution.

As a result of this new technology, an agreement between Seamwell International Ltd and its Joint Venture partner, the state-owned China Energy Conservation and Environmental Protection Group (CECEP) was signed in 2011, observed by Prime Minister Cameron and Premier Wen Jiabao of China during his visit to the UK [9]. This multinational Joint Venture would not have gone ahead without the industrial capability offered by the new "linear UCG gasifier" panel design. The resulting US\$1.5 billion clean coal project at the YiHe Coal Field in the Inner Mongolia Autonomous Region of China is the first use of UCG technology on a commercial basis and it has reduced environmental impact compared to a traditional coal-fired power plant. The 1,000 MWe power generating facility planned will operate for around 25 years and produce 5 billion KWh, consuming approximately 12 million tonnes of coal each year [10]. Although initially developed for the YiHe coalfield, when rolled out in other coalfields, the application of this design has the potential to provide clean energy from several hundred billion tonnes of coal that would otherwise have remained inaccessible.

Highlighting the significance of the new panel design, the Seamwell International Director writes:

"The new linear UCG gasifier panel design developed for use under extremely weak roof conditions at the YiHe coalfield is a significant breakthrough in UCG technology, enabling underground gasification of over 720 million tonnes of coal resource in this coalfield alone, which otherwise is not possible with the use of current conventional UCG designs. The geology and the weak roof rock conditions experienced at the YiHe coalfield is a common characteristic of all coalfields in Inner Mongolia, which holds 770 billion tonnes of coal resource. This new technology is aimed at providing clean energy from several hundred billion tonnes of Inner Mongolian coal, which would otherwise remain stranded."[B]

The first two wells at the YiHe coalfield were drilled in August-September 2011 and subsequently evaluated for further engineering designs of the "linear UCG gasifier". Seamwell International has, to date, invested approximately US\$4 million in the YiHe project and it is planned that the first syngas production using the new panel design will take place during the summer of 2015 [B].

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Prof Durucan and Dr Korre act as the main subsurface technology advisors to the Seamwell International (UK) - China Energy Conservation and Environmental Protection Group (CECEP) Joint Venture project [11]. As well as providing the new UCG panel design, they advise Seamwell International on the geological and coal resource evaluation and life cycle environmental impacts of the industrial value chain and CO₂ capture and storage systems in order to minimise the environmental footprint of the power generation scheme.

5. Sources to corroborate the impact (indicative maximum of 10 references.)

- [7] Visiongain, "The Underground Coal Gasification (UCG) Market 2012-2022", 145p. (2012) [http://www.visiongain.com/Report/920/The-Underground-Coal-Gasification-\(UCG\)-Market-2012-2022](http://www.visiongain.com/Report/920/The-Underground-Coal-Gasification-(UCG)-Market-2012-2022) (Archived at <https://www.imperial.ac.uk/ref/webarchive/lrf> on 5th September, 2013)
- [8] Confidential reports on YiHe Coalfield Underground Coal Gasification Scoping Plant Subsurface Design" and " YiHe Coalfield Underground Coal Gasification JORC Reserve Report" submitted to Seamwell International-China Energy Conservation and Environmental Protection Group (CECEP) on the new UCG Panel Design, January 2012.
- [9] <http://www.seamwell.com/downloads/CECEP%20press%20release.pdf> (Archived [here](#) on 17/09/13)
- [10] Press Releases (2011) <http://www.seamwell.com/27jun11.html> (Archived at <https://www.imperial.ac.uk/ref/webarchive/lrf> on 5th September, 2013)
- [11] YiHe UCG Project - Resource Assessment, UCG Panel Design, CCS and Environment, Seamwell International Ltd, June 2009 - 14, Prof S Durucan PI, Dr A Korre, Contract Total: £240,000

Sources for corroboration

- [A] Chairman, Seamwell International to confirm use of the linear UCG gasifier in the new Joint Venture
- [B] Company Director, Seamwell International to confirm the significance of the new panel design and it's use in the new Joint Venture