Independent Review of Underground Coal Gasification – Report

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A report to…The Scottish Government, Edinburgh 2016

Underground Coal Gasification

A Report for Scottish Government on a Review by Professor Campbell Gemmell

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Acronyms and Abbreviations

ABC	Australian Broadcasting Corporation
ACT	Australian Capital Territory
BTEX	Benzene, toluene, ethylene/ethylbenzene and xylene
BGS	The British Geological Society
BSOR	Borehole sites and operations regulations
CA	The Coal Authority
CAR	Controlled Activities Regulations
CAT	UK Government"s Carbon Abatement Technology Strategy
CBM	Coal bed methane
CCC	UK Committee on Climate Change
CCS	Carbon capture and storage
CH_4	Methane
CNRL	Cluff Natural Resources Limited
CO_2	Carbon dioxide
CO	Carbon monoxide
CoMAH	Control of Major Accident Hazards
CoSLA	Convention of Scottish Local Authorities
CoRWM	Committee on radioactive waste management
CRIP	Controlled retractable ignition point/retracting injection point
CSIRO	Australian Commonwealth Scientific and Industrial Research Organisation
CTL	Coal to liquids
CV	Calorific value
DBEIS	Department of Business, Energy and Industrial Strategy
DECC	Department of Energy & Climate Change
DEFRA	Department for Environment, Food & Rural Affairs
DMIT RE	Department for Manufacturing, Innovation, Trade, Resources and Energy
DPP	Director of Public Prosecutions
DTI	Department of Trade and Industry
EASAC	European Academies Science Advisory Council
EEA SC	European Environment Agency Scientific Committee
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ELR	Environmental Liability Regulations
EP	Environment protection
EU	European Union
FDI	Foreign Direct Investment
FoE	Friends of the Earth
FoES	Friends of the Earth Scotland
FoF	Firth of Forth
GHG	Greenhouse gas
GRO	Gasoline range organics
GTL	Gas to liquids
GW	Groundwater
H_2	Hydrogen
H_2O	Water (also steam)

HIA	Health impact assessment
HF	Hydraulic fracturing (commonly of shales)
HSE	Health and Safety Executive
HTFT	High-temperature Fisher-Tropsch
IED	Industrial Emissions Directive
IPCC	Intergovernmental Panel on Climate Change
LCA	Life-cycle assessment
LVW	Linked vertical wells
MoD	Ministry of Defence
MW	Megawatt
NHMRC	National Health and Medical Research Council, Australia
NO_2	Nitrogen dioxide
NORM	Naturally occurring radioactive material
O_2	Oxygen
PAH	Polyaromatic Hydrocarbons
PI	Public inquiry
PPC	Pollution prevention and control regulations
PSR	Pipeline Safety Regulations
QLD DEHP	Queensland Department of Environment and Heritage Protection
QLD DNRM	Queensland Department of Natural Resources and Mines
REPPIR	Radiation (Emergency Preparedness and Public Information) Regulations
RSE	Royal Society of Edinburgh
RSPB	Royal Society for the Protection of Birds
SA DMITRE	South Australian Department for Manufacturing, Innovation, Trade, Resources and Energy (now Dept. for State Development)
SEPA	Scottish Environment Protection Agency
SG	Scottish Government
SNH	Scottish Natural Heritage
SO_2	Sulphur Dioxide
SPICe	Scottish Parliament Information Centre
UGE	Unconventional gas extraction
UCG	Underground Coal Gasification
UK	United Kingdom
UKOOG	United Kingdom Onshore Oil and Gas
US	United States of America
USEPA	United States Environmental Protection Agency
VOCs	Volatile organic compounds
WHO	World Health Organisation

Executive Summary

The Scottish Government commissioned an “independent and evidenced examination of the issues…surrounding UCG”...in order to “help…formulate future policies or actions”.

A review of the literature was undertaken from February 2016 and a series of interviews was conducted with stakeholders between May and August. A great deal of material was considered relating to the Underground Coal Gasification (UCG) industry and the various demonstration, pilot and operational sites principally in Australia, Belgium, Canada, China, France, South Africa, Spain, the USA and Uzbekistan. Information on technology, operations, performance and impacts was, as noted by previous researchers, sketchy. Where appropriate, and especially given some clear data gaps, connections were sought with other Unconventional Gas Extraction (UGE) materials to explore and identify useful comparisons and learning. Given the lack of published material as well as commercial and legal sensitivities, it was not possible to assemble or analyse sufficiently detailed information for all aspects of UCG, especially industry performance in relation to environment, health and safety issues. This is surprising and disappointing given the century and more over which the technologies developed have been in use.

As to the potential for the industry to be allowed to operate in Scotland, there is a wealth of coal resource in Scotland, particularly in the Forth Estuary area and initial licences have been issued. There are deployable technologies to access the resource and bring it to a syngas processing plant and thereafter on to potential users of the gases for electricity generation, gas use or distribution and chemical industry uses.

However, against the backdrop of Scotland‟s regulatory and public policy systems and the reasonable expectations of the Scottish public in relation to engagement, operator performance and management of the whole life-cycle of the technology‟s use, it is extremely difficult to conceive of UCG progressing into use at this time. Of particular concern is how the deployment of UCG would fit with:

- Scotland‟s ambitious climate change, energy and decarbonisation targets
- Reasonable expectations of public engagement and support
- Reasonable public expectations of both regulatory and operator performance
- Effective, adequately skilled, resourced and joined-up planning and regulatory systems
- Clear existing concerns over the apparent record of performance of the industry world wide thus far and the lack of data from effective demonstration of the technology in use
- Insufficient arrangements for management of the long-term, not least potential impacts and in the compact environment of central Scotland

Response to the Brief

In terms of results, set against the requirements and structure of the brief (see Annex1), they are as follows:

- The potential magnitude of UCG reserves in Scotland, their commercial potential and relevance to wider energy and industrial opportunities.

  The resource is substantial, with greatest potential in the Midland Valley coals in and around the Clackmannan Syncline, especially the Clackmannan coalfield and in the East Fife coalfield. Hitherto inaccessible unexploited coal of appropriate characteristics and at suitable depths appears abundant. Life-cycle assessments of costs and production for an UCG operation at scale do not exist. The commercial value depends upon gas market prices and competition, quality and volume of gas, consistency of throughput, local use versus transport costs and impacts, import substitution issues and costs of offsets/life-cycle etc. It appears the most practical scenarios involve use of the gas close to the syngas plant, combined with storage of CO_2 in robust long-term stores.

- The key challenges, including environmental and public health, drawing on relevant international experiences.

  No assessment of liabilities management is available in terms of remedying failures or covering long term monitoring, abandonment etc. Conditions worldwide have been diverse making general conclusions about challenges difficult to reach and substantiate. Very few studies exist addressing the issues objectively and thoroughly. There is no Health Impact Assessment (HIA) available. Environmental impacts from trials have been documented in part and environmental statements as well as prosecutors‟ accounts are available. There are few well-documented cases. Uncertainties, the nature of the anecdotal evidence and issues raised by regulators and local communities merit concern and further systematic data collection around water and waste management, gas releases and other local impacts, especially in near-surface cases. In addition to poor data, the lack of a directly comparable operational environment worldwide – in terms of depth, sub-estuarine context, adjacent urban populations, for example - adds to uncertainties.

- The issues that are of most concern to communities and stakeholders.

  Community views strongly suggest a lack of confidence in the regulatory system, operators‟ performance, management of risks and liabilities, their likely involvement in shaping or benefitting from the operations, and a clear belief that this is not the right direction to be going in at this time, or for the foreseeable future. A low carbon clean economy with low environmental/community damage is sought. Concerns include subsidence, earthquakes, air quality, waste and water issues, local blight and reputation, the likely nature and duration of employment opportunities and local transport impacts among others. Perceptions and industry history as reported have already impacted on the view of likely impacts and operator care etc. There is a general concern as to why exploiting UCG is necessary and over whether there is a favourable balance between costs and benefits to the public, especially if operations go wrong or facilities are abandoned.

- Whether the current regulatory framework (Exploration, Planning, Environment, Marine, and Health and Safety) is adequate and sufficiently integrated, and any key gaps.

  The regulatory framework is potentially adequate but is currently fragmented, insufficiently clear and does not fit well together for the ease of use by the operator, for the integrated protection of the environment or for the reassurance of the public. Given the nature of the industry, the absence thus far of any actual applications and little technology precedent, this is not necessarily surprising. Views vary widely about the adequacy and performance of the regulatory systems depending upon which stakeholders are asked. Regulation is potentially complex, burdensome and insufficiently clear or robust to be fit for purpose. The fit between the land-use planning and Environment Protection (EP) regimes as well as the number of parties involved raised concerns among regulators, community and other experts and stakeholders. The last remaining active operator currently interested in Scottish sites is simply seeking clarity on the likely licensing and operational rules. There is a strong case for simplification, integration and improved communication and, if UCG were to progress, appropriate funding and skills provision.

- How the potential development of Underground Coal Gasification reserves in Scotland would sit with the Scottish Government‟s commitment to reduce greenhouse gases.

  Greenhouse gas (GHG) budgets are not well understood nor are the contributions of different energy technologies. Production of methane as well as carbon dioxide and other GHG gases does not automatically or directly translate to gases released to the atmosphere. Conversion, combustion, fixing into materials, flaring, fugitive releases and storage all affect the final contribution. Some of that depends upon markets and on operators‟ regulated performance. There is a clear view from those expressing an opinion that UCG would not fit well with reducing GHGs and is potentially strongly contradictory. This is especially seen as the case without any removal/storage/offset or compensation method being combined with the gas production, such as Carbon Capture and Storage (CCS), as UCG could only increase carbon dioxide and methane levels in the atmosphere. Even conservative estimates of the resource and how much could be accessed and processed into syngas suggest that this would exceed a reasonable view of our remaining carbon budget. Measured/controlled releases of gases as well as fugitive ones are stated as concerns. These concerns seem reasonable. The case for methane from this source, as a net neutral substitute for imported gas, viewed against the UK‟s and Scotland‟s targets, has not been made in detail and neither the UK Climate Change Committeee (CCC) nor work undertaken for Department for Energy and Climate Change (DECC, now DBEIS) more recently, appear to address this convincingly. The additional concern is whether this would be seen as undermining Scotland‟s perceived leadership in climate change management and representing and promoting the low carbon transition, damaging the moral and practical exemplar stance achieved so far.

- Whether the technology exists to allow for safe extraction, with particular reference to relevant international experience and lessons.

  There is a spectrum of performance worldwide but technologies clearly exist for locating and accessing the coal resource and initial gasification and extraction of product gases. Largely, in narrow technological terms, operation of exploration and gas extraction has been demonstrated. Production, especially over the longer term has only been undertaken in a few cases and, where there are any data at all, there appears to be evidence of performance failure. As no long term “at-scale” life cycle operation has been completed and recorded, and no detailed environmental performance or health records, it is extremely difficult to respond to this point. The performance of Linc Energy and other operators appears to provide evidence of significant environmental impacts and anecdotal exposures of workers to toxins resulting from operational failures. A number of these failures have resulted in prosecutions progressing and soil contamination having to be addressed, for example. Health and safety impacts are reported although the evidence is poor. Cougar and Carbon Energy in Australia appear to have closed off their operations successfully. Linc‟s Hopeland site has been taken into government hands in Queensland to ensure proper management and decontamination of the site at public expense. These three demonstration pilot sites were all operating at lesser depths than would likely be the case in Scotland. Suspended operations, in most cases, where there are any data, do not appear to have major ongoing impacts. But it must be stressed that long term monitoring regimes for the environment or health are largely absent. Angren (in Uzbekistan) and other longer operating sites have poor or inaccessible data to draw robust conclusions. A contingent “yes, possibly” to the simple question of existence of technology for extraction is possible to reach but would be based on taking absence of evidence as evidence of absence. Establishing credible baselines, firm planning and licensing conditions and subsequently enforcing robust regulatory, monitoring and liabilities management arrangements, would be paramount.

- How to successfully and constructively engage with communities and environmental groups in a meaningful, constructive and objective basis on Underground Coal Gasification.

  It is hard not to conclude that it is already too late. As to methods, there is a wealth of available expertise and some good examples of engagement techniques and approaches to involve local communities and much that could be learned from that. Public perceptions have, however, already been established and hardened by international as well as local experience. Aspects of this perception are potentially erroneous and based, for example, on UCG or Coal Seam Gas (CSG) from overseas or the Hydraulic Fracturing (HF, shale “fracking”) industry‟s earlier practices and experience in the USA, or other oil, gas and coal operations as well as often on rather selective, activist information and interpretations. Some of these materials are at least partly accurate however, as experience from Australia appears to confirm and some UCG operators, having been taken to court, fined, gone into liquidation, not having been held effectively to account for proven incidents etc., have caused widespread reputational damage and passed costs and impacts onto the public. Conventional sector oil and gas experts indicated off the record that they were concerned about working too closely with the unconventional sector for fear of reputational damage. Former miners expressed concerns about their experience of gas management and pollution issues as well as questioning if liabilities would be taken seriously. The arguable lack thus far of industry and government leadership here, or anything perceived as objective at an early point in development, has led not just to suspicion and scepticism but to full-blown activist opposition. Whilst the general public may know much less than activists, it seems that their views have already been shaped by media attracted to colourful, scare-mongering stories and a lack of differentiation between operators or technologies or geologies and locations. In the context of a precautionary approach to hazards and stringent approach to risk management as well as recognizing the relative paucity of information and a lack of directly comparable operating environments, engagement would start from a low point. Turning this around would be extremely difficult. Possible, but unlikely, in my view.

Summary Observations and Recommendations

There is a Scottish UCG resource. Technology exits to exploit it. There is related, but not analogous experience worldwide. There is public concern generally and locally. Operators, experts and the public share concerns about viability. Costs and time to market, earnings against the world gas price market, place in that market – substitution, etc. are evidently industry issues. In regulatory and policy terms, there is both a history of incidents of pollution and losses of containment, few longer term operations at scale and a serious issue to face of achieving Scotland‟s carbon/GHG (Greenhouse Gas) trajectory without an operational storage method, where CCS would be able to play a significant role. Full life-cycle provisions have not yet been addressed anywhere.

These issues together suggest that, while the industry could be allowed to develop, it would be wise to consider an approach to this issue based upon a precautionary presumption whereby operation of UCG might be considered only were a series of tests applied and passed. These tests would be in relation to the practicality and safety of the full UCG life-cycle - the end to end planning, licensing, extraction, processing, use, closure and abandonment regime including provision for long term management, reinstatement and monitoring.

Analysis suggests five interconnecting tests:

Test 1 Global/Climate Fit - Is the exploitation of UCG consistent with current and foreseen climate change imperatives and commitments made internationally and to Scottish, UK and EU climate protection measures and the minimisation of further greenhouse gas (GHG) releases?

This would likely require the coupling of any extraction with CCS arrangements or some other robust and validated sequestration method at least commensurate with the gas production envisaged (carbon dioxide (CO_2) and methane (CH_4), plus other effective GHGs identified of concern at the time). The potential for hydrogen (H_2) supply, and a “hydrogen economy” more generally is an avenue also worthy of consideration. The connections between energy policy and current and foreseeable mix and the GHG consequences – including addressing gas markets and actual releases to atmosphere - need careful further scoping. This is especially the case given the likely timetable to move from planning, regulatory and operator preparatory actions to start-up at demonstrator scale to full-blown operations and consideration of how this fits with the downward trajectory of emissions under existing targets. The timetable – and costs and energy impacts - to deliver CCS is equally significant.

Test 2 Public/Community Support – Is there sufficient public support to achieve constructive or even neutral local engagement?

The dimensions of engagement would include local and general understanding and sufficient support in terms of perceived confidence, understanding and acceptance of benefits versus costs/impacts and specifically approval – via elected representatives, or, via call-in methods, support of national government - of application to operate through the land use planning system. Engagement approach could be supplemented by benefit sharing approaches such as have been used by enlightened developers engaging around some wind farm and small hydro schemes where a community trust as well as forms of community ownership have been developed and applied. The public engagement needed to achieve local and general support would require significant effort and consequent transformation given evident current attitudes.

Test 3 Operability - Does the technological capability exist safely and consistently to extract gas by UCG, convey it to a syngas processing facility and on to distribution and/or use?

If UCG can be demonstrably safely operated (and life cycle completed), at the intended scale, as independently assessed other than by operators or advocates or at least adequately demonstrated to relevant regulators for licensing, principally Coal Authority (CA), Scottish Environment Protection Agency (SEPA) and HSE (the GB Health and Safety Executive) as well as to meet planning requirements, then it could be envisaged. This relates to both Tests 2 and 4. The specific geologies, coal/gas qualities, depths etc. of the Scottish operating conditions may well need to be tested further before demonstration and operation near or at scale could be licensed. Angren, Swan and Majuba (see Annex 3) are all different geological settings and Australian and South African examples are much shallower as well as generally being in less populated areas than the Forth margins. Demonstrating operability is an issue as is to whom it should be demonstrated. If data on health and environmental context and performance exist they should be shared. If they do not, they should be credibly and urgently sought, prepared and communicated.

Test 4 Regulation - Does the regulatory regime exist to license and safely manage the operation of the UCG life-cycle so as to give confidence and reassurance to the public, workers, operators and regulators?

This requires the appropriate mapping (for public health, health and safety, land use planning and environment protection, including relevant subsets - marine etc.) of all of the relevant elements and their practical, effective and efficient integration so as to give operator, regulator(s) and public the confidence necessary. Achieving this will require not only operators to perform so as to meet the challenge, i.e. a good environmental statement is a necessary but not sufficient requirement, but regulation will require greater understanding and engagement, greater communication and coherence between the components, and integration and simplification of components into a compelling proportionate whole. If there were applications, how would these be handled and, as in other complex cases, what is the whole mission, are science and process clear, who has and needs which powers, and is this a set of series tasks or done in parallel? Untested without a real application, current demarcations and the edges between jurisdictions and resources appear challenging and suggest the need for enhancement to deliver the best dedicated expertise. Ultimately, to be effective and efficient, I would argue that some party and individual literally should be in charge overall. Not necessarily a single regulator, as the Smith Inquiry has suggested, but a *primus inter pares* lead operating in a panel or task force model with a collegiate approach would be beneficial. The New South Wales (NSW) CSG model, with the NSW EPA as lead, seems to be working well, for example. Ideally, although the planning, licensing and performance management elements need separation and separated authority, minimising complexity, sharing expertise and applying this together to the case in question seems to offer real benefits.

Test 5 Issues of the long-term - Does the liabilities management regime exist whereby there can be confidence that the life-cycle of the operations can be concluded with no unmanaged or unaffordable costs and impacts on and burdens to the community affected, to the environment or to the public purse?

Bonds, insurances, monitoring, compensations and remediation practices would need demonstrably to exist at the outset, or at a relevant and controllable early point in the development process, and be sufficiently protected again to provide confidence of their long term robustness. Operators, regulators, local and national government might sensibly consider pro-active openness, sound baselines established well in advance, up-front engagement around hazard and risk, with sound and shared understandings of aspirations, approach to management, approach to handling failures and consequences, explanation of similarities and differences with experience and practice elsewhere etc. This would all be necessary. Financial provisions have been considered by some specialists but this needs, on the basis of experience with the late stages of a number of industries, coal included, not to be considered as a theory not really affecting those responsible at the outset by the time the risk crystalises, but a fundamental part of the due diligence and commitment required to operate and an essential insurance against failures.

There are several connections between these tests. There are also several critical issues and gaps in the areas covered and, whilst potential actions to address them can be identified, it is clear that, at this time, full operation or even trialling of the technology at scale in the Scottish regulatory, planning and cultural environment, or anything of comparable standards elsewhere globally, has not been undertaken and would face serious challenges. Without addressing the issues and gaps, it is impossible realistically to assess hazards or their management fully and hence the risks presented and the concomitant requirements for adequate achievement of community and worker safety, the protection of the environment or public confidence generally.

There are large operational and gas budget uncertainties – partly circular, related to the market development needed for methane and hydrogen, as well as the challenges of controlled and fugitive emissions, no viable storage model and the final

CO_2 and CH_4 GHG releases. But given these factors, *and* the lack of UCG industrial performance data, *and* all set against Scotland‟s world leading climate and energy commitments, the need for renewable technology development and deployment, as well as decarbonisation objectives generally, there is a persuasive case that pursuit of UCG is not the right approach.

It is also not a choice we need to make right now, as the coal remains available for future use as and when better full-cycle technologies or better processes, storage methods and market conditions exist. Also, this appears, especially without a carbon/GHG offset method, to be a potentially expensive and demanding method – when infrastructure not currently in place is considered, for example, as well as issues of coal impurities and gas quality - for obtaining a gas requiring refining before use and where methane supply is both uncertain and would directly and indirectly further contribute to Scotland‟s carbon emissions. Research, development and demonstration effort on technology, regulation, monitoring and satisfactory engagement of the communities likely to be affected to secure their support and relevant benefits etc. is also needed and currently missing.

Consideration of the possible or ideal approach to permitting the operation of UCG would then require the positive response to all of these tests and gaps indicated above, not necessarily beyond all doubt but to acceptable degrees.

At this point, it does not appear, that the tests could be met. In which case, it would appear logical, the current moratorium being justified, to maintain it, or, as in Queensland, to progress towards a ban for the foreseeable future. As circumstances suggest, either arrangement could be revisited in due course.

Introductory Statement

I do not receive any income from nor have any interests in the Unconventional or Conventional Oil and Gas sector. This study was solely funded by the Scottish Government.

Also, by way of introductory scene setting, it is important to state that this is not a rigorous academic peer reviewed research publication or a report by a career academic or team. Nor, given the challenges in obtaining evidence, should it be considered and exhaustive review. I was approached in October 2015 and engaged early in 2016 to undertake a review of UCG by late summer 2016. This is a report of that review conducted involving the assembly and consideration of available literature, a series of interviews with key stakeholders and advisors and the assessment of a number of submissions over a period of c.48 days work. These elements were taken together to provide a broad overview of UCG, set against the issues and requirements laid out in the brief. Errors and misinterpretations are my own. But I have sought to consider the range of relevant factors relating to the potential exploitation of UCG and offer Scottish Government my findings, observations and recommendations based on my own judgements and interpretation of the materials considered, from this country and from relevant projects and publications worldwide. The judgements made come from 30 years spent in executive and non-executive positions in public bodies concerned with the space between industry, environment and community. I have worked in a range of roles in economic development, community regeneration and environment policy and its implementation. I was in the period 2001-14 working in environment regulation where I led first the Scottish Environment Protection Agency and then the South Australian Environment Protection Authority.

I am a consulting partner at Canopus Scotland, Professor of Environment Research, Policy, Regulation and Governance in the College of Science and Engineering at the University of Glasgow and Adjunct Professor at the University of South Australia.

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I would also thank the project leads in Scottish Government especially for their support and many interactions during the process. Thanks too to the Scottish Government Library and especially to Lesley Oliver at the Geology Shop/Library at BGS at Lyell House.

My thanks as ever to Avril for direct and indirect support.

1 Introduction and Background

1.0 The brief for this work, its initiation, terms of reference, scope and requirements for the reports to be provided from this review are set out at Annex 1. Following the Moritorium on Underground Coal Gasification (UCG) introduced on 8 Oct 2015, I was commissioned to conduct an "*independent and evidenced examination of the issues and evidence surrounding Underground Coal Gasification*", in order "*to help the Scottish Government formulate future policies or actions.*"

Backdrop

1.1 A number of key pieces of work have been done that set the scene for or relate directly to UCG in Scotland. They are Jones et al (2004), DTI (2006), Shafirovich and Varma (2009), Osborne (2013), the Scottish Government (2014) Report on Unconventional Oil and Gas by the Independent Expert Scientific Panel and Moran et al (2013) Queensland Independent Scientific Panel Report on UCG Pilot Trials. A useful, simple briefing for parliamentarians on Unconventional Gas was provided by SPICe in July 2016, (http://www.parliament.scot/ResearchBriefingsAndFactsheets/S5/SB_16-63_Unconventional_Gas_Frequently_Asked_Questions.pdf). It contains some material on UCG.

1.2 The main sources above will be considered in greater detail later in the report. At the outset, however, it is worthwhile observing that, as a result of reviewing material for this report, there is apparently very little new overview material published, in the areas of geology, regulation or technical fields relating to the UCG facets being considered here, in the last decade. Such reviews as exist tend to have come from industry sources, including experienced advocates and contracted academics, often from a technology or marketing perspective. Also, while some more detailed material has been produced in narrow technical areas of unconventional gas extraction (UGE), it often actually focuses on shale-gas rather than including UCG in any detail and also cites the same early work as providing fundamental scoping or content.

1.3 In 2004, the British Geological Survey, (BGS), (Jones, N.S. et al) produced a study of the UK coal resource with potential for application of new exploitation technologies and it identified the broad nature of a significant coal resource across Scotland. This lies mostly in Carboniferous age coals across the Midland Valley of Scotland – from east Fife to Machrihanish as well as around Canonbie in the Solway area, and in Jurassic bituminous coals around and offshore Brora in East Sutherland (see Fig. 1). The most substantial seams exist in the Midland Valley and the best known are in the eastern half, many outcropping around the margins of the River Forth and lying under the estuary itself. The 2004 report, which remains the signal overview work for this subject, assessed the coals area by area for potential under conventional surface (opencast) and underground mining, coal mine methane, abandoned mine methane, coalbed methane, underground carbon sequestration and underground coal gasification (see Fig. 2). It is with that latter category (UCG) that this review has been concerned.

Fig. 1 Map of Scottish Coalfields – with thanks to BGS

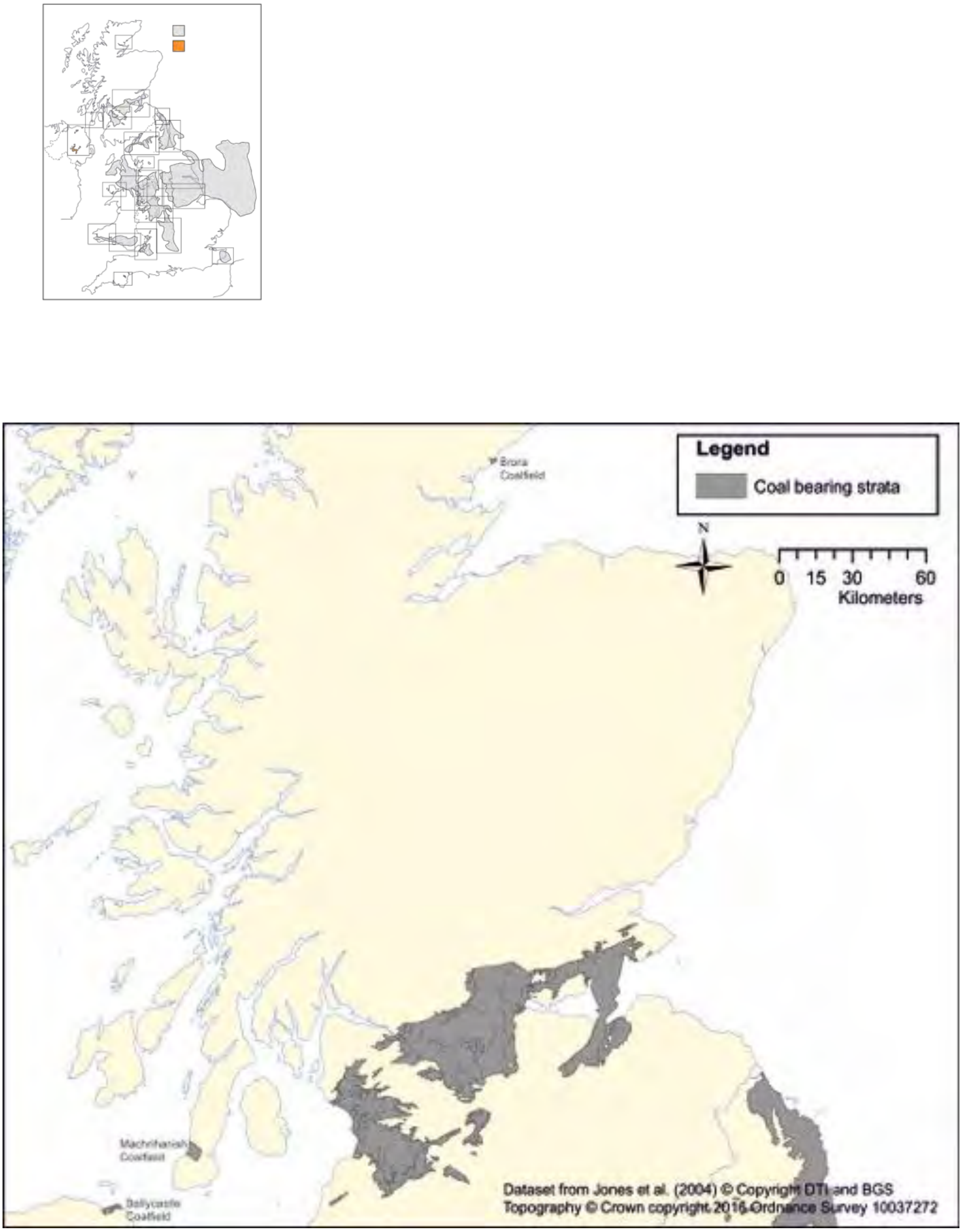


Fig. 2 Areas of UCG Potential in the Midland Valley of Scotland – with thanks to BGS

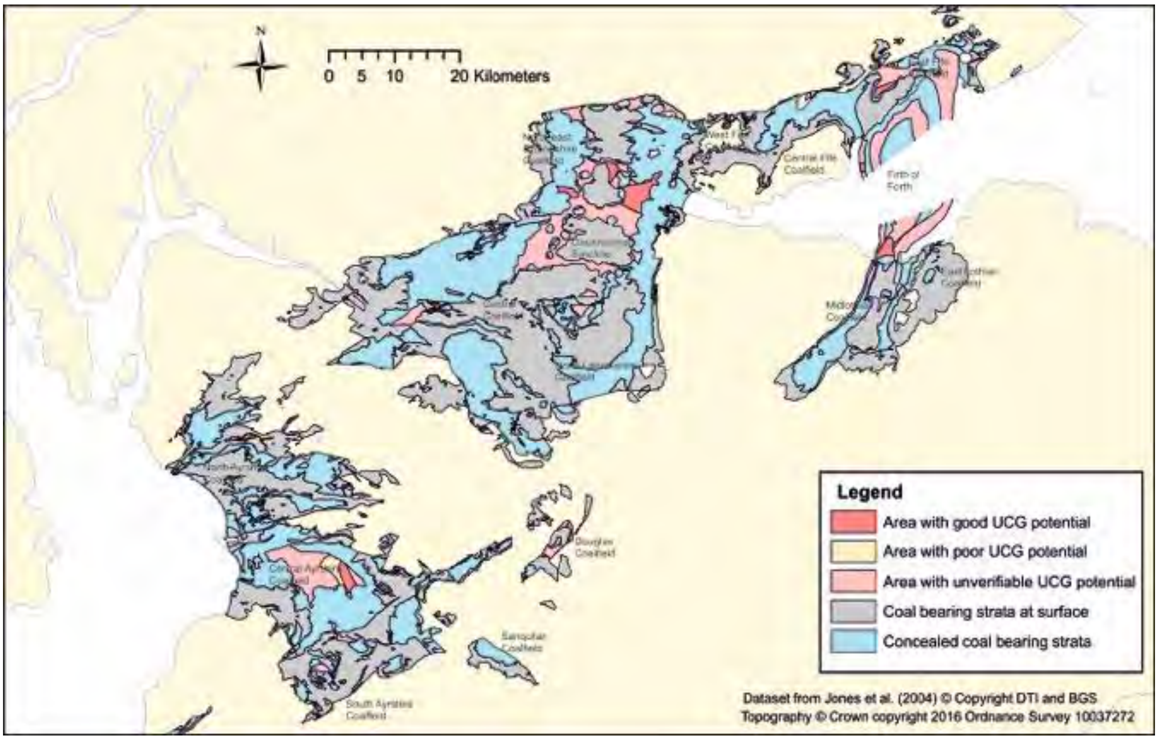


Fig. 3 Technology Schematic of UCG Operation (courtesy of keyseam/CornerStone Magazine)

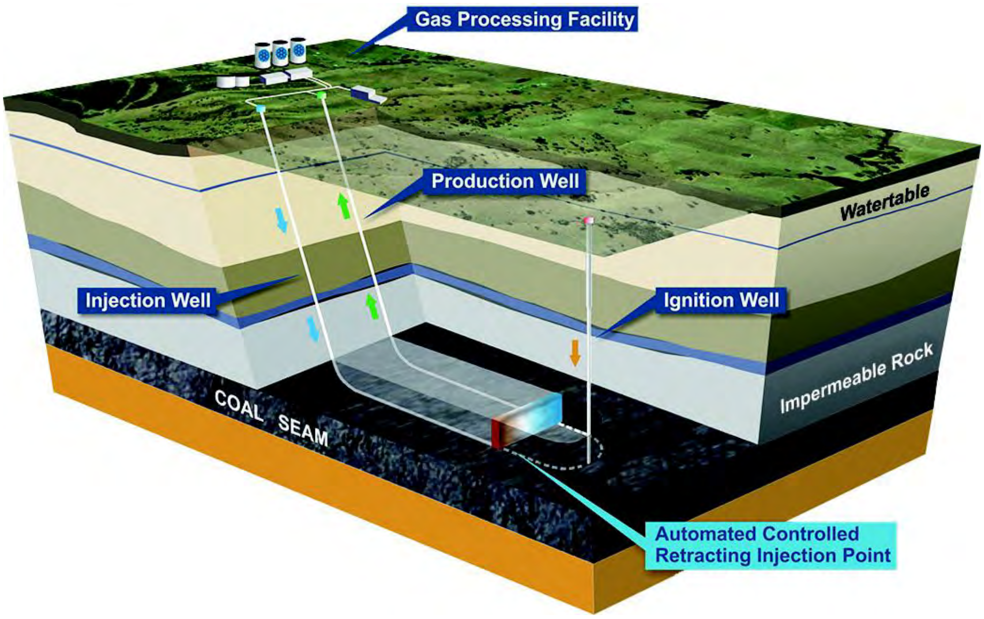


Fig. 4 Schematic of UCG (courtesy of UG Europe/AEIE; LEMAR and Skochinsky Institute)

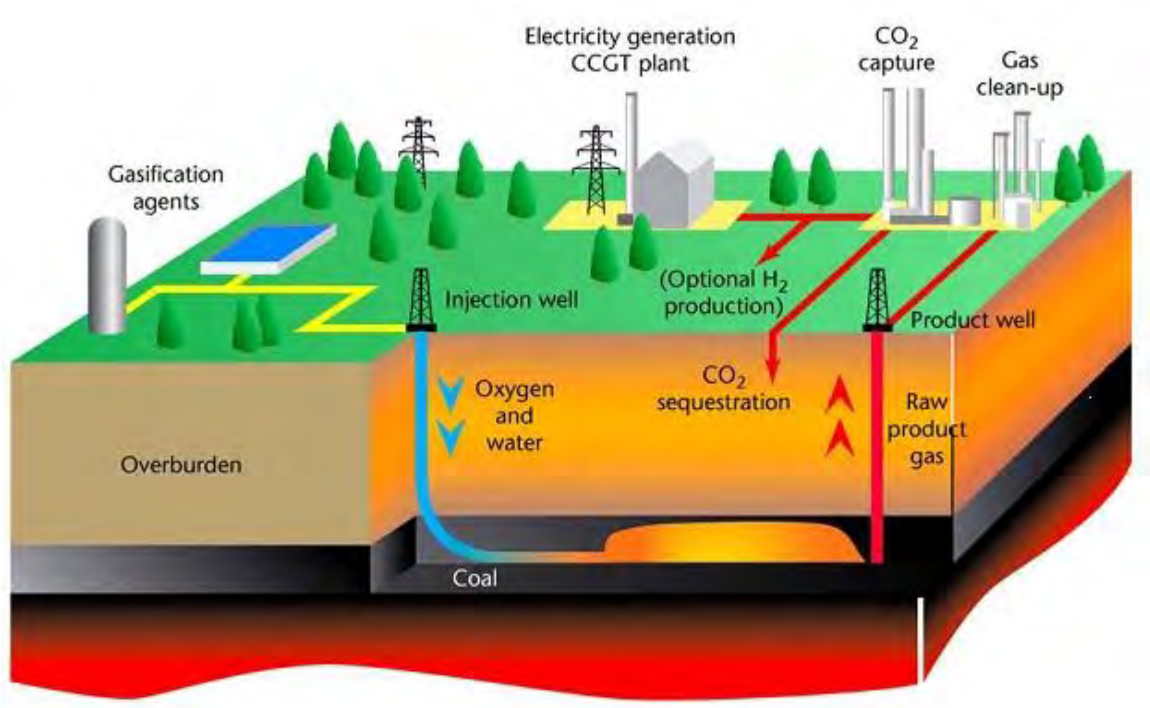


Fig 5a Chinchilla UCG Works, Queensland, Australia. (Courtesy of Linc Energy)

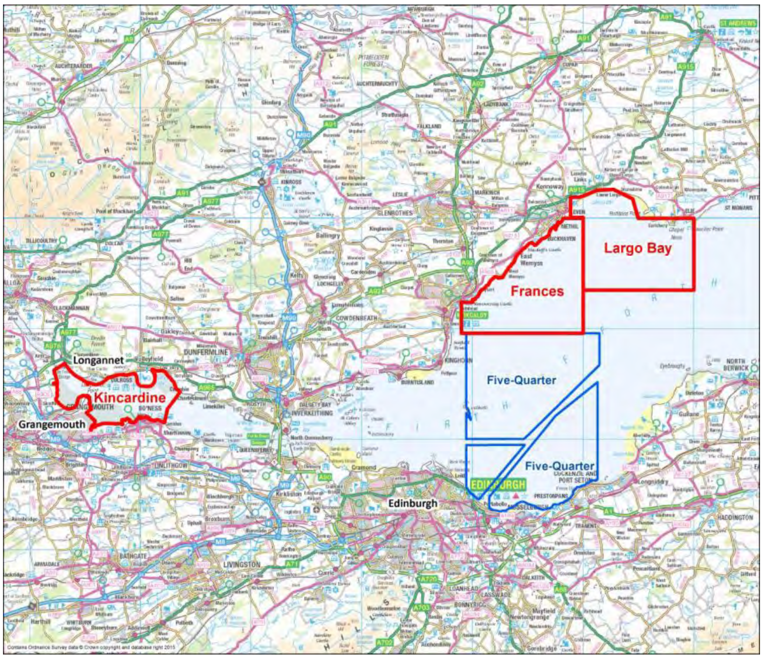
Fig 5b Cougar Energy‟s Kingaroy UCG pilot works, Queensland. (Courtesy of Cougar Energy)

Fig.5c El Tremedal, Spain – EU Pilot UCG Project (courtesy of Purdue University, AEIE and UG Europe)

1.4 Figures 3-5 give an initial impression of the processes and technology involved in UCG and the broad appearance of surface operations in examples in Europe and Australia. This will be addressed in detail in Chapter 3 in particular.

1.5 The 1994 Coal Industry Act empowers the Coal Authority to license UCG activity, starting with conditional licences normally for three to five years for exploratory work both on and offshore. Six such licences have been issued in Scotland. There is a licence covering Solway UCG potential and five in the Midland Valley/FoF area. As confirmed by CA at 23 September 2016, two will expire at December 2016 (Musselburgh and Central FoF, held by Five Quarter), two (Kincardine and Largo at July/August 2018) and one (Frances) at April 2020. The Kincardine, Largo and Frances licences are held by Cluff Natural Resources Ltd. (CNRL). Coal Authority guidance and classifications frame UCG operations and require engagement of the applicant with DECC (now DBEIS), MoD and relevant other bodies - in this case SEPA, HSE, Crown Estate, Marine Scotland and the local authority.

Fig 6 CA Licence Areas in the Firth of Forth (FoF) at March 2016 (data from CA)



1.6 The general feasibility of extracting gas by UCG in Scotland, specifically in the context of the rocks under the Firth of Forth (FoF) was researched by a team at the Institute of Petroleum Engineering at Heriot-Watt in 2004-5, published in 2006 for the then DTI, co-funded by them, Scottish Enterprise and Scottish and Southern Energy http://webarchive.nationalarchives.gov.uk/20090609003228/http:/www.berr.gov.uk/files/file30689.pdf

1.7 This report (DTI, 2006) concluded,

"This initial feasibility stage has shown that the coal geology under the FoF is suitable for a large-scale UCG project supplying gas to existing power stations and chemical processing in the area. The surrounding geology and hydrogeology in the lower reaches of the river are also favourable to UCG operations."

1.8 It continued that,

“The next phase is a detailed investigation of the geological conditions of the near-shore target areas. This will involve new exploratory drilling, a 3D seismic survey and a consultation process, with directional drilling specialists to design the long- reach wells and underground completion for the UCG process. The potential for local CCS needs to be further investigated. Significant investment will be required and a phase of consultation, economic evaluation and further work on UCG as a clean coal option under the Government‟s CAT Strategy is anticipated. The study has also suggested areas of further research in CRIP (Controlled Retraction Injection Point) control and down-hole operations.

1.9 “A successful development in the FoF could lead to widespread adoption of near-shore UCG on the NE coast of England, the South Wales coast and around the Mersey area. The export potential of the technology could be very significant.”

1.10 It also stated that,

“Previous scoping studies suggested that the coal basins of the River Forth could provide a suitable site for the first UCG project in the UK. Other studies have indicated that the most significant environmental concerns for UCG are the risks of groundwater contamination through gas escape and leachate migration. Careful site selection, process control and post-gasification site management should minimise those risks.”

1.11 Essentially this set out the main headline issues for UCG at the time and these largely remain the case.

1.12 The overall context for consideration of UCG issues is set in terms of climate, geology, energy policy, environmental, health and safety and other operationally relevant regulation including the initial land-use planning arrangements. The EU, UK and Scottish legal frameworks are also critical and issues span a wide range of subjects and jurisdictions. Much of the relevant material on other unconventional hydrocarbons and unconventional gas extraction, whilst not directly transferrable, is potentially of value and broad considerations of resource efficiency and use as well as integrated planning of the utilisation of underground dimensions of the planet could be considered in scope.

1.13 Points of entry for these subjects and their literatures include:

EEA SC (European Environment Agency Scientific Committee) Report and links considering how best to integrate consideration of aspects of the underground.

http://www.eea.europa.eu/about-us/governance/scientific-committee/reports/the-use-of-the-geological-underground

and, for example the EU-level work done by EASAC

http://www.easac.eu/fileadmin/Reports/EASAC_ExecSummary___Statement_Shale Gas_Extraction_combined.pdf

For simple visual understanding of the technology, operational issues and how UCG works – Professor Colin Snape"s (2013) presentation:

http://www.ieaghg.org/docs/General_Docs/Summer_School_2013/colin_Snape_UCG_SEC.pdf

For public health,

http://www.ukoog.org.uk/images/ukoog/pdfs/Guidelines_for_Addressing_Public_Health_in_Environmental_Impact_Assessments_for_Onshore_Oil_and_Gas.pdf

and, generally the Smith Shale Gas task force, Scottish Independent Expert Panel and Queensland Independent Scientific Panel reports, to be considered further below, in addition to references above.

1.14 I would also stress here that not least given the confusion evident in the public mind and in the media about the technologies involved in UGE, generally, I have sought not to use other UGE literature unless there was no or poor UCG coverage of a specific area and the use of other sources is helpful to allow seemingly valid inference or interpolation. This is the case for some aspects of issues around markets, community, health or regulatory frameworks but should not be interpreted strictly. It is also important to observe that while some technology and geology basics remain the same, economics, operational activity and politics among other factors continue to develop and so some material is quickly out of date, as developments (oil price, actively interested private operators, overseas legal cases etc.) during the preparation of this report have shown. And at this point, I would argue that we simply do not know enough to address the various aspects of UCG satisfactorily and, were the industry to be allowed to progress, a contemporary assessment of conditions and refreshing of key dimensions would be highly advisable. This will be clarified later.

1.15 The subject of UCG has been under consideration and addressed periodically for a century and more. Several key studies, some already mentioned, have taken place and these key works are extremely useful. But there is not an accessible or comprehensive literature on UCG. More recently, for UGE generally and for shale gas (hydraulic fracturing, HF) specifically, three pieces of work are very important. One was the Scottish Government (2014), the Independent Expert Panel Report which can be read and considered on its own merits without further glossing here. Secondly the Queensland Independent Scientific Panel on UCG (QISP/Moran et al, 2013) to which I will return. But thirdly, in the UK context, one of the more comprehensive recent UGE studies and processes that considered relevant issues and made firm recommendations to the UK Government on how to progress, albeit for HF, is the Smith Task Force"s work and it is very useful.

1.16 Lord Chris Smith chaired the Task Force on Shale Gas during 2014 and 2015. https://www.taskforceonshalegas.uk . "The Task Force on Shale Gas was launched in September 2014 to give careful consideration to public concerns, and to provide an impartial and transparent assessment of the potential benefits and risks of shale gas extraction to the UK." It reported Final Conclusions and Recommendations on 15 December 2015. Its conclusions were as follows: "Shale gas can be produced safely and usefully in the UK, and can help the UK with the transition to a renewable economy, provided the strictest environmental standards are in place." This is their overarching conclusion, but they concluded that "exploratory drilling should go ahead as soon as possible, in order to establish clearly how much gas is available and what sort of industry might be possible."

1.17 The report found that, "provided the highest regulatory and industry standards, (are applied) there is no more risk to the public from fracking than other comparable industries." Chris Smith went on: "Our conclusion from all the evidence we have gathered over the past year is clear. The risk from shale gas to the local environment or to public health is no greater than that associated with comparable industries provided, as with all industrial works, that operators follow best practice."

1.18 "The size of the UK industry‟s impact will depend on its (as yet unknown) potential output. We recommend that a number of exploratory wells should be allowed to go ahead, under the very strict environmental safeguards that we have outlined in our previous reports, in order to establish a much clearer picture of where and how much recoverable gas there is in the UK. Only when we have a better understanding of how much gas could be recovered in the UK will the public be able to make an informed decision as to whether they support it."
The Task Force is convinced that gas has a role to play as an interim energy source over the short and medium term. However, the Task Force insists that even exploratory drilling must not be allowed to restrict or prohibit the ongoing development of a renewables and low-carbon energy industry to meet the UK‟s mid-to-long-term energy needs. In its third report the Task Force called on Government to commit to applying its energy specific revenue to investment in R&D and innovation in CCS (Carbon Capture and Storage), and is therefore disappointed at the government‟s decision to withdraw their £1billion support for CCS demonstration projects.

1.19 "A summary of final recommendations and best practice is as follows:

- Transparency must be placed at the heart of any nascent shale gas industry. Operators must agree to full disclosure of the chemical content of materials used in shale gas exploration and production and agree that the specific composition will not exceed levels mandated by the Environment Agency. The Task Force does believe operators must do everything possible, and be transparent, in seeking to minimise the effects that their works will have on nearby residents.
- Baseline monitoring of air, land and water should begin as soon as a site has been identified.
- Operators must be held to the very highest standards for well integrity. Operators must commit to using only the very best materials and techniques, and to allow independent monitoring of the site, with the community involved in an oversight role, to ensure that any indication of a failure of well integrity can be identified quickly and remedied.
- The process of "green completions", recently made compulsory in the US, should also be mandated in the UK for production wells. The Task Force would wish to see no venting of gases, and for the exploratory phases small time-limited flaring permissions granted only when necessary.

- Local residents should have a direct role in monitoring any operations in their area. Monitoring of sites is essential. The Task Force believes that, in order to foster trust between operators and the communities in which they wish to work, inspections must be carried out by an appropriate regulatory body with community representatives able to attend to ensure complete transparency.
- The Government must commit to ensuring that the regulatory system for the shale gas industry is robust and fully resourced. The existing regulatory system is currently fit for purpose, as it will inevitably take time for a new industry to grow. If a shale gas industry does develop, however, the Government should explore the possibility of creating a bespoke regulator specifically to oversee this industry, to assume the current responsibilities of the Environment Agency, Health and Safety Executive and the regulatory responsibilities of the Department of Energy & Climate Change.

1.20 "On the economic impacts explored in the fourth report, the Task Force is convinced that a shale gas industry in the UK has the potential to create thousands of jobs directly and support a wider supply chain indirectly. If it proceeds, the Government must commit to appropriate skills training in areas in which shale gas production will occur. The Task Force concluded that a domestic shale gas industry provides a clear means of strengthening the UK‟s energy security and mitigating against potential risks to energy supply. Lord Smith said, „Without exploratory drilling the economic impacts of shale gas remain largely unknown. However, we make two strong recommendations to make sure the benefits are felt. First, the Government must commit to appropriate skills training in areas in which shale gas production will occur. And second, we recommend that operators and Government specify details on how the creation of successful production sites will benefit residents living nearby.‟

1.21 "The Task Force further called on operators (or UKOOG) to outline exactly how they intend to provide £100,000 of community benefits for exploratory well pads. Local communities have the right to know how they will benefit and, where possible, should have a say in how they benefit. For all wider community payments, the industry and Government should define exactly what is meant by „communities‟. Additionally the administration of community benefits payments should involve residents and local authorities working together, supported by the operators."

1.22 I have quoted this at length as I think these findings have considerable merit and bear some comparison with consideration of UCG. I do not necessarily share their conclusion however, as I will go on to clarify, not least as there is for me a logical break between accepting that resource scale and impacts are insufficiently known, public engagement and compensation arrangements are unclear, and there is a fundamental dependence on high standards of operator performance and regulation, both being urged and assumed to achieve best practice, i.e. between identifying the issue and it being satisfactorily addressed. As this is not always achieved, it is hard to set this permissive conclusion comfortably against the precaution required.

1.23 The Queensland Independent Scientific Panel (QISP) Report on UCG Pilot Trials, undertaken three years before the state imposed a ban on UCG, took a related, permissive approach but proposed a further review stage be undertaken when work should stop at the end of the pilot phase, before full operational scale demonstration. QISP (Moran et al, 2013) sets out life cycle process elements for UCG and acknowledges receipt of a great deal of data from the three (then two) operators involved. The report covers very useful ground, as follows:

1.24 “Underground coal gasification (UCG) is a technology that has been in use in various forms for many decades. Queensland is possibly currently leading the world in UCG technology development and testing. The Queensland government needs to come to a conclusion regarding UCG in the context of its broader energy policy in the medium and longer terms. A great deal of coal that is economically inaccessible to mining (too deep or poor quality) and from which coal seam gas will have been extracted could potentially be a source of syngas in the future.

1.25 “The Queensland government approved three UCG trial sites over a period of years with a view to making their own assessment. The Independent Scientific Panel (ISP) was established to assist government with these assessments. The main roles of the panel were to apply individual and collective expertise to analyse, assess and evaluate various technical and environmental factors and to report the outcomes of the trial activities including recommendations on the prospects and future management of UCG in Queensland.

1.26 “The two companies that have provided pilot trial reports that are the subject of this assessment are Linc Energy and Carbon Energy. Both companies have developed versions of the controlled retracting injection point (CRIP) technology. [Note that the precise description of the abbreviation varies between industry sources.] The reporting process was designed around the combination of the operational life cycle (site selection -> commissioning -> operation -> decommissioning -> rehabilitation) and a conventional process industry risk assessment. Both companies have used their extensive technical databases, which have been gathered from experience of a number of gasifiers with evolving technologies. The integration of technical data into the necessary risk assessment is an important challenge in the process.

1.27 “Both companies have demonstrated capability to commission and operate a gasifier. Neither company has yet demonstrated their proposed approach to decommissioning, i.e., the self-cleaning cavity, is effective. The ISP remains open to the possibility that the concept is feasible. However sufficient scientific/technical information, particularly relating to decommissioning, is not yet available to reach a final conclusion. Important work has been undertaken but more is yet to be done. For example, neither company has gained access to a gasified cavity, sampled it and provided information on the current contents and condition of surrounding materials.

1.28 “At mid-2012, neither company had completed a burn of sufficient duration to create a final cavity of the dimensions that are expected under a commercial process. Until this is done it is difficult to come to a final conclusion regarding the technology. Given this situation, the ISP believes it would be pre-emptive to consider commercial scale. However, given the considerable investment by the companies and Queensland government to date, and the undoubted future importance of UCG as a viable energy source of global significance, the ISP is of the view that the gasifiers currently operating should be permitted to continue until a cavity of significant dimensions is available for full and comprehensive demonstration. At that time, commercial scale UCG facilities could be considered. There is more work to be done on the design and environmental and operational safety for multi-panel operations.

1.29 “Given the pilot project reports presented, the ISP has come to three overarching recommendations and eight specific recommendations. The latter cover each of the life cycle stages (5), the interaction between CSG and UCG (1) governance (1) and the question of commercial multi-panel operations (1).

1.30 “Following consideration of the materials made available to the ISP from companies and in the public domain, the ISP has come to the following overall conclusions.

- Underground coal gasification could, in principle, be conducted in a manner that is acceptable socially and environmentally safe when compared to a wide range of other existing resource-using activities.
- The ISP is of the opinion that for commercial UCG operations in Queensland in practice first decommissioning must be demonstrated and then acceptable design for commercial operations must be achieved within an integrated risk-based framework.

1.31 “Consequently, the ISP makes the following three (3) overarching recommendations.

Overarching recommendation 1.
The ISP recommends that the Queensland government permit Carbon Energy and Linc Energy to continue the current pilot trials with the sole, focused aim of examining in a comprehensive manner the assertion that the self-cleaning cavity approach advocated for decommissioning is environmentally safe.

Overarching recommendation 2.
The ISP recommends that a planning and action process be established to demonstrate decommissioning. Successful decommissioning needs to demonstrate the self-cleaning process and/or any necessary active treatment. To achieve this:

1. A comprehensive risk-based plan for decommissioning must be produced;
2. The Plan must take account of the fact that both companies now have connected cavities suitable for demonstration [Linc Energy is still gasifying];
3. The Plan must include at a minimum a conceptual model and relevant numerical models, a sampling and verification/validation strategy, and event-based milestones that, where possible, are time bound.
   Two significant phases are recognised: a. Sampling of the zone surrounding the cavity; and b. Direct cavity access.
4. The government must establish a process by which the plans and their implementation are assessed for adequacy.

Overarching recommendation 3.
The ISP recommends that until decommissioning is demonstrated, as per Overarching Recommendation #2 no commercial facility should be commenced.”
Moran et al/QISP (2013)

1.32 I will return to this work and its relevance in the technology and conclusions chapters of this report.

1.33 Business and Market Context

Not only has the price of oil (and gas) fallen and risen during the period of this review but the number of overtly interested players and active licences has reduced during this year. First Riverside Energy and then Thorton New Energy let their interests lapse, with Five-Quarter picking up some of the licences albeit temporarily. At this point, following the announcement that it was ceasing to trade in the UK, Five-Quarter Energy Ltd. also exited from Scotland in March 2016, leaving Cluff Natural Resources (CNRL) as the only company remaining in play with conditional licences in place. Whilst other company data were gathered, I have only presented in Annex 2 information concerning CNLR in the Scottish context. Nonetheless, Cluff announced that it too would cease all expenditure relating to its Forth projects in January 2016.

1.34 Five-Quarter in particular stated directly (on their website - http://www.five-quarter.com) that "global market conditions have changed, North Sea activities are in rapid decline, and there is considerable uncertainty about the direction of Government strategy for energy. Five-Quarter has been unable to persuade the British Government to provide supporting statements to allow it to proceed with negotiations for FDI." Uncertainties, created or influenced by both government and gas markets, as well as their knock-on impact on investors both in the UK and from overseas, while not the only factors, were raised repeatedly as inhibitors of development. Without extension, or further action by CA, all current licences will expire in 2018.

1.35 Review Approach

This report responds to the brief as set out by SG, with one specific change. In discussion with the project team, with members of the group responsible for the previous report on unconventional gas, SG (2014), upon which aspects of this report builds, and with some of the main stakeholders in preliminary conversations, it became apparent that a standing advisory group reflecting these interests, was unlikely to work. It was clear it would risk being burdensome, more costly, challenging to manage and unnecessary, not least given the ease of direct access to the main individuals and bodies involved, the strongly divergent views held by some of the parties, inevitable conflict over such information as might be used and differing interpretations based upon fundamental philosophical differences as well as the changing, more polarised nature of the Scottish context. Inputs have been secured from all of the relevant groupings and individuals recommended by Scottish Government and identified by me and by those I initially contacted, as having useful and relevant contributions to make at this stage. It is my judgement that the interview process allowed a safe space for contributors to input and a standing group would not have facilitated a better process or a stronger or clearer outcome.

1.36 Identifying the structure of the Report

In considering the UCG resource and its potential, this review has involved looking at a range of framing dimensions: climate, geology, energy policy, economics, regulatory and planning issues and their fit, community views, operational experience and issues of the longer term - liabilities and monitoring, as well as the areas of uncertainty identified. The rest of the report will largely follow these section elements in the following chapters before making recommendations for the future. I have looked at these issues through researching cases, sites and operators and the available and accessible literature on the technology itself and cases written up for publication as well as interviewing 35 people from 23 stakeholders identified as critical to assessing these aspects of context, the history of UCG and lessons so far, the nature of the resource, its future potential and the factors relevant to safe and supportable exploitation.

1.37 Interviewees are listed in Annex 2A. Interviews were generally conducted using a simple questionnaire. Some interviewees chose to respond to the advance sight of the questionnaire as well as participate in the interview. Some did not address all questions based on expertise, authority or personal preference. Some supplementary information from these interviews is appended at Annex 2B. Others contacted and who provided input to the study via telephone or skype conversations or email exchanges are at Annex 2C. Of those approached, only Ofgem declined to participate.

1.38 The sites and operations considered for the study and about which data were sought are listed in Annex 3.

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2. Geology

2.0 This chapter sets the fundamental starting point for consideration of the potential UCG resource. Presentation of the issues was aided by inputs from interviews with Dr Alison Monaghan at BGS and Professors Haszeldene and Shipton (Annex 2) as well as senior staff at the Coal Authority and consideration of the literature.

2.1 As indicated in the Introduction above, in 2004 BGS (Jones, N.S. et al) produced a study of the UK coal resource with potential for application of new exploitation technologies and it identified the broad nature of a significant coal resource across Scotland. That report and discussions with BGS provide the basis of this chapter.

2.2 This resource lies in three main components:

> 2.2.1 the largest province by far - Carboniferous age coals across the Midland Valley of Scotland – from east Fife to Machrihanish
> 2.2.2 Carboniferous coals around Canonbie in the Solway area, and
> 2.2.3 in Jurassic bituminous coals around and offshore Brora in East Sutherland.

2.3 The most substantial seams exist in the Midland Valley, in the Ayrshire and Douglas Coalfields in the west, in the Central and Clackmannan Coalfields in central Scotland and the Fife and Lothian Coalfields in the east. These latter two are the best known and the richest prospects in terms of knowledge, thickness and likely quality and accessibility, largely from prior deep coal prospecting and workings around the margins of and under the Firth of Forth. But from the estuary in the east to Machrihanish in the west the geological markers can be connected and relatively speaking a lot is known about these coals.

2.4 The BGS 2004 report assessed the coals area by area for potential under conventional surface (opencast) and underground mining, coal mine methane, abandoned mine methane, coalbed methane, underground carbon sequestration and underground coal gasification.

2.5 Jones et al address UCG processes and potential and the criteria for its delineation and mapping. The quotations which follow in this section are *„Reproduced from Jones N S, Holloway S, Creedy D, P, Garner K, Smith N J P, Browne, M A E & Durucan S. 2004. UK Coal Resource for New Exploitation Technologies. Final Report. British Geological Survey Commissioned Report CR/04/015N with permission of BGS/DECC. The full report is available for download from http://www.bgs.ac.uk/downloads/start.cfm?id=1712 „*

2.6 "Underground Coal Gasification describes the process by which various combinations of air, oxygen, hydrogen and steam are injected into one or more *in-situ* coal seams to initiate partial combustion. The process generally involves the drilling of at least 2 boreholes, one to act as the gasifier and one to collect the product gases. The injectant reacts with the coal, which produces heat and drives off gases (hydrogen, carbon monoxide and methane), which are subsequently recovered through a production well. The basic chemical processes and the calorific value (CV) of the gas produced are similar to conventional industrial gasification processes, although the final gas composition is somewhat different. Compared to CBM, UCG generally produces a gas of medium CV with a heating value of about 30% that of CBM. If air, rather than oxygen, is used as a partial oxidant then a lower CV product gas is produced with a heating value of about 10% that of CBM. The other difference is that with UCG typically 75% of the energy value of the affected coal is produced as useful energy at surface, whereas with CBM it is much lower. ”

2.7 The criteria for UCG potential in the geology are,

- “Seams of 2m thickness or greater
- Seams at depths between 600 and 1200m from the surface
- 500m or more of horizontal and vertical separation from underground coal workings and current coal mining licences
- Greater than 100m vertical separation from major aquifers, and
- Greater than 100m vertical separation from major overlying unconformities”

2.8 Underground coal gasification can take place either under shallow, low pressure conditions or at depth, under high pressure. The latest UCG projects all try to work close to the hydrostatic pressure to minimise pollution spread, and so shallow schemes (100-200m) like Chinchilla operate closer to atmospheric pressure (~10 bar) than those at greater depth such as the European trial (El Tremedal, Spain) (~60 bar). Shallow operations have lower drilling costs but the disadvantage is the potential for environmental pollution and a lower CV gas. High pressure encourages methane production and cavity growth.

2.9 “For this generic study, a minimum depth of 600m has been assumed to lessen the environmental impact at surface, in terms of hydrogeology, subsidence and gas escape. This does not rule out shallow UCG for specific sites in the UK, where the local strata and hydrogeological conditions can support operations in seams closer to the surface than 600m. The 1200m depth represents the normal limit for mining in the UK, and the same figure was used for UCG on the basis of drilling costs and working pressure at surface. More work might establish that UCG can go deeper, and there are advantages in terms of energy produced in doing so.

2.10 “A seam thickness of 2m or greater has been chosen for economic reasons – greater thickness means more coal for gasification. It has also been suggested in the European studies that UCG reactions in thin seams are not generally sustainable, although the Soviets have reported that seams down to 1m in thickness can be gasified. Other factors that are important in any UCG scheme, but were not used in the mapping process were:

- Impermeable layers of strata surrounding the target coal seam
- Seam bedding dip between 5° and 30°
- Absence of any major faults in the area
- Low values for sulphur content, ash content and swelling index
- Environmental and hydrogeological conditions
- Proximity to users
- Licence conditions that might be imposed by Regulatory and Planning Authorities

2.11 “To define UCG areas, the borehole database was interrogated to identify boreholes which contained coals in excess of 2m in thickness at depths between 600 and 1200m from surface. The 600 and 1200m lines, drawn on each map, mark the lower and upper limits of each UCG resource area. It can be seen from Figure 4 (p152 in Jones et al, 2004 – a block diagram of dipping coals which illustrates how the criteria for UCG and carbon dioxide sequestration are applied) that the maximum possible resource area is defined where the 600m line intersects the top of the coal-bearing strata and the 1200m line intersects the base of the coal-bearing strata. Coal seams that met these criteria, but were less than 100m below the base of the Permian, were excluded. Boreholes that met the criteria were plotted on a base map together with the extent of underground workings and existing mining licences. The resource area could then be defined. Three resource subdivisions could be identified: good, unverifiable and poor. These are represented on the maps (in the report) as different colour(ed) zones. Good areas meet the criteria as defined above. Unverifiable areas represent regions where the UCG potential is unknown. This may be related either to the absence of borehole data, or to the lack of deep penetrating boreholes (i.e. >600m) within an area. Poor zones represent areas where coals are present at the required depths, but do not meet the thickness criteria.”

2.12 Interestingly the description of UCG processes also addresses the question of CO_2 Sequestration. It states “Because carbon dioxide (CO_2) sequestration requires that CO_2 remains in place for very long time periods, areas of coal suitable for mining or underground gasification are not suitable for CO_2 sequestration.”

2.13 “Areas considered to contain coal resources potentially suitable for CO_2 sequestration by adsorption onto coal fall into two categories:

- Areas of unminable coal seams (defined on the maps by areas where coal seams are at depths >1200m and >500m from mine workings), and
- Areas where coal seams are at depths of <1200 m, but CO_2 sequestration might take place in association with underground coal gasification or coalbed methane production

2.14 The former are regarded as primary areas for CO_2 sequestration and are identified on the maps. The latter are regarded as secondary opportunities and are not marked on the maps. Because this is an immature technology, no implication as to the methodology for CO_2 sequestration is made. Figure 4 (see above) indicates that this area is at a maximum if it is defined at the position where the 1200m line cuts the base of the coal-bearing strata. This also creates an overlap zone between the area suitable for UCG and that of the potential CO_2 sequestration area. Hence the position where the 1200m line intersects the base of the coal-bearing strata is marked on the maps.”

2.15 The Report goes on to consider risk and uncertainty issues,

“There are a number of geological factors that are important for the coal technologies and can have an impact on the exploitation of the resources; these can be viewed as risks. Many of these are described by Creedy et al. (2001). There are also areas of uncertainty regarding the accuracy of the resource assessment and mapping process. These are detailed in the following section:

2.16 *"3.2.1.4 Underground Coal Gasification*

- Heavy faulting
- Overburden composition and potential leakage of produced gases/by-products into aquifers
- Groundwater quenching the reaction
- Subsidence
- Seam thickness variability
- Coal conditions inductive to lateral cavity growth
- Fugitive emissions or migration of potentially harmful combustion products"

2.17 It also identifies under key uncertainties, mapping processes, data availability, data reliability and the mapped and real presence of faulting and hydrogeologic issues. It goes on,

"it is clear that borehole availability plays a major factor in the determination of UCG resources and uncertainty exists as to whether all resources have been identified. In order to minimise this risk, boreholes were selected at regularly spaced intervals where possible. Where resources were identified further boreholes were selected to try and produce the best possible definition of the resource area. In the deeper parts of coalfield this was not always possible due to restrictions on borehole availability. Uncertainty also exists regarding continuity of seams between boreholes related to, for example, faulting. Only detailed site specific studies can address these issues."

2.18 Jones et al describe how they calculated UCG potential. Using the areas mapped, "Two volume calculations were performed. Firstly the minimum volume of coal available for gasification was calculated, using the equation below:

Min. vol. of coal suitable for gasification ($10^6 m^3$) = „good" area (m^2) x 2(m)

This calculation was made assuming that the only minimum thickness of coal (i.e. a 2m thick seam) was available for gasification across the area.

2.19 The second calculation involved taking an average of the total thickness of coal per borehole in the areas with good UCG potential and multiplying this average figure by the area of the good polygon.

Ave. vol. of coal = suitable for gasification ($10^6 m^3$) „good" area(m^2) x average of the total thickness of coal per borehole that meet the criteria (m)

2.20 It is difficult to determine accurate resource figures due to the limitations of the borehole dataset, particularly the fact that boreholes do not generally penetrate through the entire thickness of coal-bearing strata. In these instances it is not known whether there are coals present at greater depths that may meet the criteria. Although not truly accurate, this second calculation probably gives us a more typical idea of the volume of coal available for gasification than by applying a minimum value. The figures derived from these two calculations are given in Table 7 of the BGS report.

2.21 The minimum total volume of coal suitable for UCG in the UK is nearly 5,700 x $10^6 m^3$ (~7 Btonnes), whereas the total volume of coal figure derived using the average coal thickness meeting the criteria per area is nearly 12,911 x $10^6 m^3$ (~17 Btonnes) (Table 7 again). This represents a resource of 289 years based on the current UK coal consumption of 58 Mtonnes per year (at 2004; now somewhat lower/longer).

2.22 An extract from Table 7 in Jones et al, is reproduced and edited below,

Area	Av. thickness of coal meeting UCG criteria (m)	Area of Resource (sq.km)	Min vol of coal available for gasifn (ass.2m seam) (M cu.m)	Vol of coal available for gasifn using av thickness of coal across area (M cu.m)
Canonbie	3.9	3.89	7.78	15.2
Ayrshire	2.36	6	12	14.2
Douglas	7.5	1.3	2.6	9.8
Clackmannan	2.6	22.9	45.8	59.5
Fife	3.1	3.8	7.6	11.8
Lothian	3.8	5.6	11.2	21.3

2.23 Jones et al also set out some details for each of the main Scottish UCG areas as follows:

“Ayrshire Coalfield

Conditions suitable for UCG are generally limited in this area due to the extensive nature of previous underground mining activity. However, areas with good potential for UCG have been identified. The largest area in the Ayrshire Coalfield is between Mauchline and Ochiltree. Seams proved to exceed 2m thick at the correct depths in areas not associated with old mine workings are restricted to two boreholes: Kingencleuch No 1 (Hurlford Main 2.52m at 937m) and Drumfork Farm Bore (Lugar Main 2m at 717m). These two coals are from the Middle Coal Measures. A large area of unverifiable UCG potential exists to the west of the area of good potential. Boreholes are present in this area but typically do not penetrate to depths much in excess of 600m and no thick coals have been recorded. Hence this is an area that may have potential.

Douglas Coalfield

In the Douglas Coalfield only the Callow Knowe, Douglas Bh.76 Diamond and Eggerton boreholes proved coals suitable for UCG. In the latter borehole the Manson Coal in the Passage Formation was about 8.12m thick, corrected to 4.66m for a dip of 55° at a depth of only 260m. However, this is in a mined area so has been discounted. In the Callow Knowe Borehole this seam was 2m thick at a depth of 871m. In the Douglas Bh.76 Diamond the Ponfeigh Gas (2.41m, at 623m), from the Upper Limestone Formation, and the Wee Drum (5.54m at 781m) and the Skaterigg coals (3.28m at 792m) from the Limestone Coal Formation are all considered suitable for UCG.

Central and Clackmannan Coalfields

There are three areas considered suitable for UCG in the Clackmannan and Central coalfields. These are to the north-west of Falkirk, and two areas along the Firth of Forth. Coals that meet the criteria are the Upper Hirst (Upper Limestone Formation), Bannockburn, Wester Main, Kelty Main and No.1 and 2 Jersey coals, Glassee and Mynheer from the Limestone Coal Formation. Good prospects occur northwards from Grangemouth to the area of the former Longannet Colliery and north and west of Stenhousemuir. It is possible that the good areas extend further to the south-west, into the area between Falkirk and Cumbernauld. However, there are few deep boreholes hence this area is marked as unverifiable.

Fife Coalfield

In Fife there are two small areas that meet the criteria for UCG, one onshore and one offshore. The onshore area occurs between Glenrothes and Methil, whereas the offshore area lies along the western flank of the Leven Syncline. Coals meeting the criteria include the Upper Limestone Formation Craig Coal, and the Upper Cardenden Smithy, Lochgelly Splint, Cowdenbeath Jewel and Cowdenbeath Five Foot from the Limestone Coal Formation. To the north and east of this good UCG prospect is a large area of unverifiable UCG. Here there are no boreholes greater than 600m in depth.

Lothian Coalfield

In Lothian the coal-bearing strata are limited to a narrow synclinal area between Musselburgh and Penicuik. The extensive former underground coal mining restricts the areas available for UCG exploitation. However, small areas with potential exist immediately offshore from Musselburgh and to the south-east of Edinburgh. Seams that meet the criteria include the Lower Coal Measures Musselburgh Fifteen Foot and Seven Foot and, from the Limestone Coal Formation, the Great, Gillespie and Blackchapel."

And finally, the report identifies,

"Leven Syncline

The only areas where the Westphalian Coal Measures reach depths >1200m and therefore have potential for CO_2 sequestration in unminable coals, is in the centre of the Leven Syncline beneath the Firth of Forth. Further potential may exist in the Limestone Coal Formation in the Leven Syncline."

2.24 Coal Authority (2009) describes the policy position for their licensing of UCG. The 1994 Coal Industry Act empowers the Coal Authority to license UCG activity, starting with conditional licences normally for three to five years for exploratory work both on and offshore.

2.25 Seven such licences have been issued in Scotland. Six still active although under discussion for ownership in late 2014. Now (late August 2016), 2 licences held by Cluff Natural Resources remain in effect to July/August 2018. Coal authority guidance and classifications frame UCG operations and require engagement of the applicant with DECC, MoD and relevant other bodies – in this case SEPA, HSE, Crown Estate, Marine Scotland and the local authority. This is addressed further in the chapter on Regulation.

2.26 Further relevant issues are also addressed in the next chapter on Technology and Operations.

2.27 Several related geological issues should ideally be taken into account in considering the viability of UCG operations and their hazard profile. These are not considered here in detail but merit fuller analysis.

A Issues of interaction with prior mine workings.
Good planning and controlled combustion would seek to avoid dubious nearby structures. Separation criteria already exist but these are "rules of thumb" and would need to be tailored to issues of local structure and gas and liquid movements. Ruling out gas connection with adjacent voids or differing pressure environments or where gas presence could accentuate panel burns would be expected to be factored in to operations.

B Issues of post-combustion response
Gas and liquid connectivity from pore space level to transit along faults and fracture zones to movement along a hydrological gradient may all occur. Hydrostatic pressure at depth may accentuate some and constrain other effects. Late combustion products, tars etc., might be expected to be retained in cavity and might slowly become mobilised in the groundwater. Depth, hydrostatic pressure and low transmission potential would inhibit this being significant.

C Post Combustion gas storage
Use of coal seams where UCG has taken place in a single or set of panels has been suggested for CCS but largely discounted as non-viable in the short term and an additional hazard without further integrity and structural analysis given the disruptive effects of combustion, flexure and hydrostatic responses.

D Burn-out
What happens when cavities (combustion chambers and panels) collapse (B&C) – a fully burned out seam of 2m thickness across a front of a number of metres and along a seam of tens of even hundreds of metres might be expected even with hydrostatic encouragement to close or groundwater incursion to limit closure would create a flexure or collapse of centimetres to meters extent. These would be expected to have some seismic impact, potentially, though not certainly, gradually. Surface impact of this is unclear but potentially low.

E Seismicity generally
Largely unknown impacts for UCG although some impacts have been reported from shallow sites in Australia. Base level data and modelling would be advisable.

F Hydrogeology/Groundwater impacts
This area is addressed under Regulation and Environmental Impacts but in addition, baseline assessment of groundwater chemistry is discussed by Ó Dochartaigh et al (2011) and the data were used to inform BGS and SEPA approaches to groundwater (GW) assessments and characterisation of GW generally.

2.28 Uncertainty

Several authors and stakeholders have referred to what is well known about the geology of the Midland Valley of Scotland, one of the very best known areas of coal geology worldwide. The work of BGS and its predecessors, and the Coal Authority (CA), as well as commercial contractors and BGS contract work for licence applicants and bore hole operators etc. has added to the work produced by mining engineers and owners over two hundred years and more. It is also clearly one of the more complex geologies found, by comparison with some locations where UCG has been developed and tested in South Africa, Australia, Russia/Uzbekistan or North America.

2.29 The plate edge location of Scotland over a large part of geologic time has resulted in significant collisions and stretching of the crust producing faulting and fracturing of the main coal units and the surrounding geology. Although the depths involved in the case of the major coal seams meet CA criteria, there are issues of uncertainty that are relevant to how exploitation could progress.

2.30 Borehole coverage and mine records deteriorate rapidly moving east and south from Kincardine into the Forth and similarly west from the edge of the Leven syncline as well as at greater depth and further offshore. Fault heave magnitude and direction are less certainly known and quanta and trajectories are plotted literally with dotted lines and question marks. More drilling would clearly help fill data gaps.

2.31 The way in which the geological location where UCG combustion takes place is by definition remote from the surface and from easy access and hence difficult to model or monitor accurately. The pressure at depth is both related to gravity and overburden mass and hydrostatic pressure affecting the void spaces in the rocks and the liquids and gases present there. Opening up a cavity and causing coal and gas to combust and then removing this creates forces of expansion and then recovery, with heating and cooling also taking place. Surrounding pressure generally would seek to fill a created void. Gas is being extracted and liquids, i.e. groundwater, and secondary gases in the geology would enter the space and re-equilibriate. Structural relaxation and flexure would also occur. Therefore, the net effect of hydrostatic impacts is somewhat unclear and groundwater quality and connectivity across the geological units cannot be certain at this point. It might be supposed, however, that, where impermeable capping or low transmissibility units are present and the water bodies are at such depths or separated from any current conceivable use, risk is minimal. Seismicity is known to occur naturally here and is associated with some UCG activities. Not enough is known locally to assess these factors. Assumptions can be made about groundwater salinity, disconnection from higher aquifers, effective aquitards, minimal gas and water movements, low seismicity, small flexures of burned out cavities, minor collapses. Certainty does not exist.

2.32 It should be stressed, however, that uncertainties can also be over-played. These issues relate to some extent to groundwater and rock extraction, and certainly to exploitation of oil and gas offshore. What we must ask and consider is what is our appetite to accept these hazard factors and what arrangements would be put in place to understand and mitigate them. Robust preparatory work to enhance knowledge, including bore work would be critical, as would the establishment of a fit-for-purpose monitoring network to assess changes in well-understood baseline conditions above and below ground during any demonstration pilot and subsequent operations.

2.33 Summary

Coal of relevance to UCG exists in significant quantities in the central of the three provinces in Scotland. For now, the coal bearing geologies of the north (Brora) and the south (Canonbie), as well as the Machrihanish component of the Midland Valley coals in the west can be set aside in practical terms. They could be exploited but would be unlikely to be a priority. Similarly the western half of the Midland Valley area is less likely to be developable for now. The FoF remains the most likely area to be considered for exploitation, is the best known, mapped and explored – a position enhanced by the additional work undertaken by Belltree (2014) and has extant licences. It has been studied in some considerable detail and has, despite being substantially fractured and interrupted in some parts, the potential to be exploited by existing technologies. The major seams within the province which meet BGS/CA criteria for depth, thickness and quality have been initially assessed and potential operators have engaged with licensing and other regulatory bodies and sought to plan on the basis of their understanding of the resource.

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3. Technology and Operational History and Issues

3.0 This chapter benefitted not only from a review of the literature but also from inputs provided in interviews and conversations with senior staff in the Coal Authority, regulators, former miners, academics and critically, industry experts.

3.1 According to Younger and Gonzalez (2010),

"The world‟s first UCG experiments were carried out beneath Hett Hill in county Durham in 1912, by Sir William Ramsay". Progress was halted by the First World War, and the technology was later neglected except in the former Soviet Union, where up to twelve UCG-based power plants were in operation in the mid-20th Century. Although UCG production declined when natural gas reservoirs were found in the region, a 100 MW UCG power plant remains in production at Angren in Uzbekistan. Various pilot UCG operations have since followed elsewhere in Asia, Europe, the United States and Australia."

3.2 In the Geology Section above, the approach to licensing UCG taken by the Coal Authority is mentioned. The CA, as well as HSE, essentially requires the operator of both generation, extraction and processing of UCG gases to demonstrate their method of operation and the environmental and safety dimensions of such operations.

3.3 The technologies involved are a combination of coal and oil and gas technologies and, as UCG is a gasification process, which happens to take place "in situ" or underground, the methods relate to accessing, initiating ignition in, maintaining combustion in and extracting product gas from an underground combustion chamber shaped by the geology of the location. The technologies and operational methods involved begin with the German engineer, William Siemens in the 1860s and have been refined and augmented by work in Durham and across the world since. A good summary for the time was set out by Burton et al (2007) and useful overviews are also in Lavis, Courtney and Mostade (2013) and in Osborne (2013). Osborne covers a very wide and detailed scope and "in situ" gasification, as UCG is sometimes called, is promoted as "a likely long term option in the safe, economic recovery of the large resources of coal unlikely to be considered mineable."

3.4 Process and Technology

The processes involved in the UCG industry – drilling, gas production and Syngas refining are described in Burton et al (2007), Lavis et al (2013) and a large number of other sources covered in the bibliography.

3.5 The chemical process at the heart of Underground Coal Gasification is the engineered injection of a blend of gasification (normally O_2, air, H_2O/steam) agents into the coal resource, their ignition, coal combustion and collection of the product gas.

3.6 Adrianopoulos et al (2015) describe the process in more detail.

"Following ignition, the reagents support the gradual transformation of the coal seam into syngas which is collected, transported to the surface and, depending on its composition (mainly H_2, CO, CO_2 and CH_4), can be used either as chemical feedstock or as fuel for power generation. The employment of directional drilling techniques to engineer the injection and production boreholes represents a significant advance, which is adopted from the oil and gas industry". Early methods were based on the use of two shafts – one for injection purposes and the second for venting or extraction."

3.7 They go on, "The two UCG subsurface layouts discussed in this paper are the Linked Vertical Wells (LVW) and the Continuous Retracting Injection Point (CRIP) geometries. Both geometries belong to the shaft-less UCG methods although their operational details are distinctly different." Adrianopoulos et al (2015)

3.8 As to technology more specifically and the different models, Jones et al (2004), describe UCG, as elsewhere, as

"the process by which steam and air or oxygen is injected into a coal seam via a surface injector well. These injected gases react with the coal to produce a combustible gas that is collected at the surface via a producing well (Creedy et al. 2001). Methane is a product of pyrolysis and gasification and its formation is favoured under high pressures. As part of the gasification process a cavity develops as the coal burns. Wilks (1983) predicted that the cavity that develops around the injection well would be pear-shaped, assuming that the reaction processes were uniformly distributed around the reactor and that the roof collapses immediately into the cavity formed by gasification (Creedy et al 2001). If the roof does not collapse the cavity will grow in size and some of the fluid reactant will by-pass the coal and the reactor efficiency will decline. This results in an O_2 rich product gas or a rise in the product temperature (Creedy et al. 2001). Hence in the UK, the UCG process is aided at depths greater than 500m by the high in situ stresses that characterise the UK Coal Measures which should ensure caving and thus reduce the possibility of by-passing (Creedy et al 2001).

3.9 "There are three main forms of UCG. The first involves drilling a series of vertical boreholes, gasifying the coals and relying on a combination of high pressure air fracing (sic)(pulses of air to open the cleats in the coal) and the natural permeability of the coals to extract the gas. This type of UCG generally takes place at shallow depths. An example of this is the Chinchilla project in Australia (Walker et al. 2001; Blinderman & Jones 2002). The low permeability of most UK coal is thought to preclude this method, although there may be exceptions in some coal structures. The second type of UCG takes place in existing or abandoned coal mines (e.g. Liuzhuang Mine, China). In this process mined galleries are sealed off, air is injected into these galleries, the surrounding coal is gasified and the gaseous products piped up a shaft or borehole to the surface. The European and later US trials have involved the gasification of coals in which the production and injection wells are connected by in-seam drilling techniques. UCG is a cost effective means of extracting energy from coal because it avoids the high costs associated with mining and constructing a surface gasifier (typically hundreds of million pounds) and leaves ash and dirt underground. The recent technological achievements in UCG have been addressed by Creedy et al. (2001) and reference should be made to this report for details."

3.10 From these earlier documents it is clear that there are variations on a few themes - early shaft and bore models, which have become more sophisticated and controlled; mine and gallery and chamber models also developed early and applicable to some geologies amore than others and then CRIP - controlled retraction injection point – models whereby more precise drilling methods can be used, especially in deeper coals and narrower seams to allow for ignition points and gas injection and collection to be achieved on a more mobile and controlled basis as the "panel", or coal gasification unit, within a seam is burned out.

3.11 UCG worldwide

In this section the locations where UCG has been trialled and operated worldwide are identified. The material which follows also indicates the technology and method used at these locations in a range of cases.

3.12 Shafirovich and Varma (2009), Burton et al (2007), Creedy et al (2001), Green (2009), Lavis et al (2013) and FoEI/Monk (2016) all set out sequences and partial listings of UCG sites and although there are several discrepancies around timing and some other details, these do appear to address the most relevant cases and this has assisted in compiling the list at Annex 3. This is still not complete however and more research as well as greater operator openness would be required to make it complete and exhaustive as well as supply comparable information on each physical operation and what it has achieved as well as its impacts. Nonetheless, Annex 3 provides an overview of UCG projects worldwide and their approximate dates, depths and some salient details.

3.13 Jones et al (2004) at 11.1.1, p 44 also set out a history of UCG,

"There have probably been over fifty or so different UCG trials and larger schemes operated during the past 50 years or so. Early UCG trials usually took place at shallow depths (<200m); for example the Newman Spinney trial in the UK in 1959 was drilled to the Fox Earth Coal at a depth of 75m (Gibb & Partners 1964). These trials were generally of short time periods (1-2 months). The exception to this were the large-scale, air-blown schemes in Russia and Uzbekistan and a test at Chinchilla in Queensland, Australia, which was initiated by Linc Energy in December 1999 and was mothballed in 2003. The Russian and Australian schemes used simple technology and produced a low calorific value gas. China has considerable experience of UCG, with 16 trials completed since 1990. Feasibility studies have also been carried out in Canada, India, Pakistan, Russia, Slovenia and Ukraine, and a small burn was conducted in New Zealand in the early 1990"s.

3.14 "Underground coal gasification has been carried out in Kuzbass, Siberia, at the Yuzhno-Abinskaya gasification plant since 1955. This involves the gasification of bituminous coal, 1.3 - 3.9m thick, producing a low calorific value gas used for heating (Walker 1999). The reprocessing volume achieved 2 million tons that constituted about 4 billion m^3 of gas.

3.15 “The Angren Coalfield is the largest coal deposit in Uzbekistan, containing about 1.8 billion tons of mostly brown coal (lignite) that is used as fuel for Uzbekistan's power generation. The Angren mine also has underground coal gasification technology in place since 1955 to produce gas for the Angren power station. The lignite seam varies in thickness from 4-20m and lies at depths of between 130-350m. The output in 1963 was believed to be about 860 $x10^8$ m^3, but present production is about half of the 1963 figure (Walker 1999).
3.16 “There was much research carried out in the 1970s, and a number of trials went ahead. The Thulin scheme, in Belgium ran from 1978 to 1986 and gasified a thin seam at a depth of 1000m. In the US, UCG research has focused on relatively shallow (100m deep) coal seams and tests were focused on the development of the process itself. However, the Rocky Mountain 1 (RM1) UGC test at Hanna, Wyoming, involved extensive site characterization, instrumentation and monitoring in order to gain a detailed understanding of the environmental and hydrogeological variables (Boysen et al. 1990; Creedy et al. 2001). Commercial projects were evaluated (e.g. at Rawlins, Wyoming), but the low cost of gas in the early 1990's prevented these projects from being viable.

3.17 “The El Tremedal European trial in Spain (1993-1998) confirmed the technical feasibility of UCG at depths between 500-700m and has shown that improved deviated drilling techniques in deep seams can provide interconnected channels suitable for use in underground coal gasification (Green 1999). In this trial a controlled retraction injection point (CRIP) system was used to control the gasification procedure (Green 1999).

3.18 “The IGCC project in Chinchilla, Australia began development in 1999, and was the first project to propose the use of UCG syngas directly in gas turbines (Blinderman & Jones 2002). The project involved construction of an underground gasifier and demonstration of the technology (Walker et al. 2001; Blinderman & Jones 2002). Approximately 32,000 tonnes of coal have been gasified, producing a low calorific value gas of about $5MJ/m^3$ at a pressure of 10barg (145psig) and temperature of 300°C (Blinderman & Jones 2002). Nine process wells have been producing gas from a 10m thick seam at a depth of about 140m (Blinderman & Jones 2002). Ground water monitoring has also been taking place in association with this trial and has revealed no contamination (Blinderman & Jones 2002). This is probably related to keeping the gasifier pressure less than the hydrostatic pressure of fluid in the coal seam and surrounding strata (Blinderman & Jones 2002).

3.19 “UCG has been under review in the UK more or less since the early Newman Spinney trials in the 1950‟s. British Coal undertook major studies in the 1970‟s and 1980‟s and trial sites were identified in Nottinghamshire area towards the end of the 1980‟s as possible locations for the European trial – in the end the trial was located in Spain, as discussed above. The current UK programme was activated in 1999.”

3.20 The DTI (2006) study by the team at Heriot Watt still appears to be valid and it sets the scene for key aspects of the work of Belltree (2014). This is the most detailed geological consideration available other than the detailed mapping and modeling capability of BGS. DTI (2006) includes 3D visualisations of well design, geo-mechanical issues and risks as well as some environmental consequentials. It also analyses economic factors and provides a very useful starting point for developers and consideration of the issues that Belltree then developed in their work for CNRL. The main area of change is around the consideration of CCS. Whilst an interesting and potentially key part of the 2006 model, this is at least, at present, beyond detailed consideration.

3.21 No other similar levels of detailed analysis have been found that relate to potential or operational sites. It is likely that these analyses exist and that much could be learned from them but the information is evidently held by developers and perhaps some regulators and is not accessible.

3.22 Dr. Cliff Mallett, the Technical Director at Carbon Energy and former chair of the UCG Association (2013-15), which has since ceased, has similarly reviewed the range of projects and technologies involved in the history of UCG from the perspective of an experienced operator. He refers (Mallett, 2015) to the "almost a hundred historical sites worldwide". He also observes,

3.23 "A commercial UCG plant has been running for many years in Uzbekistan; however detailed information on the operation or output of that plant has not been made public."

3.24 He also acknowledges in part the range of impacts and difficulties of the industry, citing the main difficulties encountered as:

* Insufficient knowledge of the site geology
* Inability to drill boreholes with necessary precision
* Operating with inappropriate gasification parameters
* Lack of understanding of the impact of the gasification process on the surrounds of the underground cavity."

3.25 He goes on then to cite the major technical innovations which have addressed the issues previously encountered (simplified here):

- Geology – advances in mining: 3D seismic surveys and computer-based geologic models
- Drilling – advances in long-hole in-seam drilling methods
- UCG Design and Gasification Process Control – development of proprietary new modelling and design capability and process methods for real-time control of operations as well as development of parallel controlled retracting injection point design (an enhancement of the previously leading CRIP method)
- Ground and water impacts around the gasifier – mine strata and gas models for prediction of deformation and gas and water inflow into mines

3.26 The (2015) article concludes,

"Since 2000, long-term UCG pilots in Australia, China, and South Africa utilizing the technologies shown in Table 2 have successfully demonstrated that deep UCG can be low cost and environmentally benign. Results from these trials continue to demonstrate that UCG‟s major challenges have been resolved and has led China to incorporate this technology into its Five- Year Plan process for resources and energy.

3.27 Recent progress and innovation have made it possible that UCG will be an important technology in the future energy mix. However, progress in nontechnical areas must be made with respect to the interrelated areas of government regulation, community understanding and engagement, and project financing."

3.28 These latter points seem especially telling, not least in the context of the subsequent Queensland ban. Also, it is again worth looking at Moran et al (2013).

3.29 "The reports produced by Linc Energy and Carbon Energy are amongst the most thorough compilations of information on any UCG pilot trials to date. A great deal of useful information and lessons are incorporated into the reports. It is not possible to do justice to the quantity of technical information provided by each of the companies in a summary set of recommendations. No doubt, over time, the companies will see fit to release at least some of this technical information into the public domain so that others are able to make their own assessments of the merits and risks associated with UCG."

3.30 Additionally, a failure to engage the public and comply with regulatory requirements and ultimately failure to deliver a viable demonstration for investors has thus far, outside Uzbekistan, prevented confident, long-term delivery of high-performing UCG. And from that latter site, the absence of data means that the story, and of particular relevance here, its environmental, health, safety and community facets, cannot be understood and evaluated.

3.31 Osborne and Gupta (2013) reported that there was, in 2011, an identification by industry experts given price and technology trends that UCG was, again, ready to take off and demonstrate its value, partly because of CRIP developments. Events from 2012-16 appear to have set this back significantly.

3.32 Technology developed in South Africa in the 1950s and thereafter had led to various coal to liquids (CTL), gas-to-liquids (GTL) and high-temperature Fischer-Tropsch (HTFT – improvements of the original 1920s process created in Germany for making synthetic fuels at c 300°C, with an iron catalyst) processes which produced "ultraclean gasoline" (diesel), petrochemicals and oxygenated chemicals, including transport fuels in the SASOL facilities. Coal derived fuels have seen significant growth in China too. The China Shenhua Group pioneered CTL projects e.g. in Inner Mongolia. A number of Chinese/South African collaborative projects have been progressed and a programme of works is in place for projects in the 2015-20 period. (see also Annex 3.)

3.33 Full lifecycle is generally poorly articulated and detailed. Full life cycle is taken to mean from scoping mapping through exploratory drilling, through production to completion, decommissioning and abandonment, including the long term reassurance visiting of the site or its capped former access wells and air, water, soil testing and testing too of liabilities management where failures have occurred etc. Considerably more is known of the front end of the life cycle than the latter components.

3.34 Interestingly, perhaps, only the Polish research and coal industry community seem to be continuing relevant detailed work, under the HUGE2 (Hydrogen oriented UCG programme, see Annex 3) and related EU programme banner, including test gas analyses and examinations of the cavities produced by UCG processes and the most accessible materials have been presented at international coal conferences, e.g. http://www.fossilfuel.co.za/conferences/2014/UCG3/Session-2/01Krzysztof-Stanczyk.pdf
This work highlights somewhat unexpected gas characteristics – very high nitrogen product with hydrogen and methane content lower than many tests - and pollution potential of combustion processes but, significantly has involved post-combustion cavity and seam analysis and is focussed now primarily on hydrogen production rather than methane and is only just beginning specifically to explore environmental performance.

3.35 The (2001) report of the then DTI‟s Cleaner Coal Technology Transfer Programme/ETSU, "Review of Underground Coal Gasification Technological Advancements is a wide-ranging overview of the technology issues and developments to that time by Creedy et al. (2001). [Interestingly this is just one of 7 reports produced between 1999 and 2009 into UCG in the UK and Scottish context]. It outlines methods and a series of the learnings from case histories at that time, including for El Tremedal. It also summarises environmental impacts and commercial issues as well as providing a view on future R&D directions. Much of this agenda remains to be tested and although the Australian demonstrators were designed with some of these attributes in mind, they have not yet been fully or, successfully, addressed.

3.36 Summary

A large number of sites have tested and piloted aspects of UCG technology worldwide over more than 60 years. Technologies have been developed that allow drilling into coal seams and coal combustion, gas extraction and processing of syngas. No operation has been demonstrated and operationalized in a context directly comparable with the FoF. Nor has any site been closed off after fully successful operation and independently assessed with reference to a robust, or any, ex ante assessment of expected impacts say on groundwater and surface environmental condition. Very little useable data appears to be available demonstrating the hazards, mitigation and results of the successful operation of a UCG/syngas system facility. Those data would ideally connect ex ante statements and expectations therefore with real results across all relevant facets of the UCG operation including environmental, health, seismic, community engagement etc. issues in practice.

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4. Environmental and Health and Safety Issues

4.0 This chapter and the next were greatly aided by inputs from SEPA, the Coal Authority, HSE, Marine Scotland, SNH and regulators past and present in a number of Australian jurisdictions as well as discussions with academics, EU officials and the literature itself.

4.1 Health issues are explicitly considered separately in chapter 6 but given the nature of the data and research material available – its relative paucity and the interconnectedness of the subjects - environment and health and safety issues are taken together here.

4.2 Evidence for impacts, hazards and risks are taken first, in this chapter, and the frameworks and arrangements for regulation in the Scottish context follow in the next chapter.

4.3 Given the material content of the coals involved in UCG, combustion/gasification has the potential to produce and liberate a variety of potentially problematic material. Releases to air and water as well as waste materials removed from the combustion site, drilling materials and treated materials at the surface, and products and wastes from syngas plant operation all require consideration. In order to understand the potential impact on groundwater of coal geologies, see first Younger and Sapsford (2004). Liu et al (2007) also describe risks of groundwater pollution, highlighting the significance of local hydrogeological conditions. Depth, transmission potential and permeability impacting on the ability of contaminants to migrate to sensitive areas and receptors were shown to be critical. This is consistent with issues addressed in the Geology chapter.

4.4 The assessment of impacts of UCG at the local, regional and national level would in all likelihood include a strategic environmental assessment of the policy and plans associated with the application of the UCG technology. “Underneath” that, an environmental impact statement would be required to address the specifics of the application.

4.5 An appropriate environmental impact assessment report would reasonably be expected to address the nature, extent, duration, intensity, probability and cumulative dimensions of impacts on the geology, hydrogeology, hydrology, water use, freshwater (and marine in the Scottish context) ecology, terrestrial ecology, soils and agricultural capability, built and cultural heritage biodiversity, waste, air quality and visual amenity. We might also expect consideration of climate impacts. All of these dimensions would then need to be considered from testing, construction, operational and decommissioning phases of the development.

4.6 A number of operations worldwide have undertaken an EIA or ES of some kind. Two examples are the Majuba EIS (SAf RHDHV, 2014) – at 215 pages, one of the more thorough and best I have seen, and that for Linc Energy at Chinchilla (Linc Energy, 2007; actually the terms of reference for their EIA, not found.). Clearly an ex ante statement is a part of the picture and an assessment of impacts during operations and then ex post, following decommissioning and during long term reassurance monitoring, might be more instructive on the realities experienced and relevant to a credible assessment of impacts.

4.7 The range of possible impacts from UCG activity includes the controlled and uncontrolled presence of –

- gases and particulates vented and flared to atmosphere as well as gathered for production and use which have the potential to escape, with associated hazards and odour.
- light, noise and vibration from operations, transport etc
- collection, storage and disposal to sewer or waste of produced and extracted liquids, waste waters from the deep and surface operations
- collection, treatment and disposal of solid wastes from drilling, gas extraction and surface processes, including ash and tars if removed
- containment of surface liquids, gases, fuels and other materials required for Syngas plant operation or from system purges and at closure

4.8 In addition to the essential consequent combustion products of carbon dioxide, carbon monoxide, hydrogen and of course methane, the condensate produced by the UCG process usually would be expected to contain organic compounds typically found in the Gasoline Range organics (GRO"s), some Polyaromatic Hydrocarbons (PAHs), Phenols and BTEX (Benzene, toluene, ethylene, and xylene). In most global jurisdictions, it would also be expected that maximum limits would be set for the release to the environment of these materials. US EPA, WHO or local standards would be likely to be, and are, commonly applied.

4.9 On top of the regulatory dimensions that would follow planning and licensing of the underground activity and the production site operations, the context of sub-marine or sub-estuarine UCG operations appears likely to mean that some aspects of the standard EIA framework and monitoring in general would be more than usually challenging. How the terms would be set and by whom is as yet also unclear but would connect land, water, pollution, marine, energy and health and safety regulatory interests.

4.10 Preliminary but highly relevant work has been undertaken by SEPA in this space and is included in Annex 2. This sets out the range of environmental hazards potentially identifiable for UCG: groundwater and surface water pollution and GW depletion, air emissions, underground explosion hazard, cavity collapse, seismicity and uncontrollable fire. In most cases at this point, the assessment is that for these hazards not enough is known as to the nature of the hazard or the effective regulatory controls likely to be required. These are being actively explored.

4.11 In order to connect broad principles to operational practicalities, data were sought from examples worldwide. US cases, projects in the period to the 1990"s (see the Livermore data from Hoe Creek for example in https://fossil.energy.gov/international/Publications/ucg_1106_llnl_burton.pdf) and even EU pilots (Creedy et al., 2001 for El Tremedal, pp 23-29), had relatively little public data. Somewhat clearer pictures emerge from Australian cases as initially indicated above.

4.12 Australia

Generally, consideration of the documented and reported experience in Australia is limited, often partial but instructive. UCG activity has largely been restricted to Queensland although related activities in the UGE grouping of technologies and operations have been running for a number of years, alongside conventional oil and gas activities, in every state and territory except ACT, most productively in Queensland, Northern Territory, South Australia and New South Wales. But whereas shale gas is minimally relevant in NSW and CSG has dominated, in Northern Territory the dominant experience has been in shale gas. Geoscience Australia (2014) provides a great deal of detail.

4.13 Groundwater quality issues and the environmental hazards associated with unconventional gas exploitation, including UCG, are reviewed in Geoscience Australia (2008).

4.14 A wide suite of conventional and unconventional coal, oil and gas technology has been deployed in Queensland and it has as a state great mineral assets. Given its active exploitation of the resources, it is perhaps the most informative area to study for this review.

4.15 Queensland

The Queensland Government gave the go ahead for a trial by three companies into the potential to develop and realise a UCG industry in the state, based on a commitment developed through the late 1990s.

4.16 In 1999, Linc Energy established a pilot UCG facility within its Mineral Development Licence (MDL) 309, 20 kilometres south-west of Chinchilla, in southern Queensland. Linc Energy gasified approximately 35,000 tonnes of coal at a depth of 120 metres below surface during a 30-month test period, with the produced syngas being flared to the atmosphere. (Linc 2007) Linc engaged technical advisers from the Skochinsky Institute (in Russia), which invented the UCG process, and brought in expertise and IP from the Yersotigaz (Uzbekistan) site - then 60% owned by Linc Energy - as operators, since 1964, of the only commercial UCG power plant worldwide. The Marubeni Corporation, Japan provided direct investment.

4.17 Following the pilot, Linc proposed to establish a full commercial-scale operation with a gas to liquids (GTL) plant for synthetic diesel and aviation fuel as well as a combined cycle gas turbine power generation plant to provide onsite power and surpluses going to the grid.

4.18 Linc (2007) articulates the terms of reference for the EIS for their Chinchilla operation and this follows an appropriate framework and appears to cover the range of aspects that might realistically be expected at that stage in the plans for the location and activity. On 11 March 2015 the state of Queensland, published on the website of the Department for Environment and Heritage Protection QLD DEHP (2016) that Linc had been committed for trial, “on five charges of wilfully causing serious environmental harm, in contravention of the (state) *Environmental Protection Act 1994*. On 11 March 2016, Magistrate Kay Ryan handed down her decision in the

Dalby Magistrates Court, determining that Linc Energy should stand trial on these charges. The Department of Environment and Heritage Protection filed a complaint in the Chinchilla Magistrates Court in 2014 with four charges against Linc Energy for allegedly wilfully and unlawfully causing serious environmental harm.

4.19 “In 2015 a further charge was commenced, also alleging Linc Energy wilfully and unlawfully caused serious environmental harm. All charges relate to operations at the Linc Energy underground coal gasification site near Chinchilla, from approximately 2007-2013, and allege that contaminants were allowed to escape as a result of the operation.

“The committal proceeding involved 12 days of hearings in Dalby and Toowoomba from 21 October 2015 to 27 November 2015. Submissions by the parties were completed on 24 December 2015.

“As the matter remains before the courts, EHP is unable to comment further on the legal proceedings. In the meantime, EHP has retained the excavation caution zone in the area and has asked landholders in this zone to contact the department if they intend to excavate to a depth of two metres or more.
Details of the excavation caution zone and monitoring being undertaken in the Chinchilla region are available at www.ehp.qld.gov.au/management/hopeland.html. ” QLD DEPH (2016)

4.20 Media coverage and reporting of the committal provided additional detail. (ABC, 2016). It was alleged that “fugitive gases from the site - including carbon monoxide, hydrogen and hydrogen sulphide - polluted a widespread area up to six metres underground. The Magistrates Court in Dalby decided the company should face trial on all five charges brought against it.

4.21 Linc Energy said it was disappointed by the magistrate's ruling, arguing the case against it was a circumstantial one. And stating,
"Linc Energy reiterates its innocence and is steadfast in its belief that the evidence put before the Court by the DEHP (Department of Environment and Heritage Protection) had glaring holes and suffered from inconsistencies, and as a result it fell well short of the standard required," the company's spokesman said in a statement.
"Should the Director of Public Prosecutions (DPP) decide to proceed further and take the company to trial, Linc Energy will be seeking a court hearing at the earliest opportunity in order to present its evidence, which so far has not been heard."
The legal action was the result of the biggest investigation ever undertaken by the department.” ABC (2016)

4.22 Court Reporting, by the Daily Telegraph (Courier-Mail affiliate John McCarthy in Brisbane) (2016) indicated,

“Workers at Linc Energy‟s controversial gas site near Chinchilla were told by superiors to drink milk and eat yoghurt to line their stomachs to prevent the effects of contaminants.”

4.23 “Linc, owned by millionaire Queenslander Peter Bond, faces a committal hearing in Dalby Magistrates Court on five charges of wilful and serious environmental harm at an underground coal gasification plant. Opening the prosecution case, Ralph Devlin, QC, said evidence, including “fingerprinting” of contaminants, would show that Linc was the only possible source. The contaminants had explosive or asphyxiating properties and included volatile organic compounds and benzene and toluene. Workers at the site also complained of health effects consistent with contaminants.

“Evidence would also be produced that a water bore 150m from one gasifier was well known for leaking high levels of carbon monoxide and was dubbed „Puffing Billy‟ by workers. Mr Devlin said staff were also seen wearing white safety suits at the site while other workers wore respirators and personal gas meters, which went off as soon as they left their dongas.”

“These witnesses are saying they felt ill and were having illness episodes consistent with exposure (to gas),” Mr Devlin said. He said workers saw large areas of bubbling on the ground at the site and one worker, Timothy Ford, sprayed dishwashing detergent on the ground and ended up with a large area covered in suds that was dubbed “Christmas in Chinchilla”.

“The evidence would also show that Linc operated the project at pressures that led to the fracturing of the geology and allowed contaminants to escape. The issues dated back to 2007 and coincided with the operational control being held by „Oleg from Uzbekistan‟ and workers would find data had been written in Russian.”

“Mr Devlin said at the early stages of the project Linc knew the environmental risk of operating its gasifiers at higher-than-allowed levels. Evidence will show Linc‟s over pressurising of the landform created new fracturing,” Mr Devlin said. “These pathways allowed synthetic gas to escape from gasifiers. The UCG test site was shut down in 2013.”

4.24 Whilst a somewhat colourful combination of journalism and court presentation, this raises a number of issues that court submissions from the state appear to substantiate.

4.25 Before the case reached trial, the Queensland Government, on April 18th 2016, announced a ban on UCG in the state. QLD Cabinet and Ministerial Directory issued a joint statement by the Minister for Natural Resources and Mines and the Minister for Environment and Heritage Protection announced an immediate ban and “committed to a legislated ban before the end of the year.”

4.26 The statement goes on,

“We have looked at the evidence from the pilot-operation of UCG and we‟ve considered the compatibility of the current technologies with Queensland‟s environment and our economic needs. The potential risks to Queensland‟s environment and our valuable agricultural industries far outweigh any potential economic benefits,” he said.

“The ban applies immediately as government policy, and I will introduce legislation to the Parliament by the end of the year to make it law. This will give certainty to the resources industry, so they know very clearly where the government stands, and to the community.

“As a government, we support our resources sector for the jobs and economic growth it generates, but UCG activity simply doesn‟t stack up for further use in Queensland.”

4.27 The statement continues, “Environment Minister Steven Miles said that the Government was also taking strong steps to address issues that had arisen during the UCG pilots. One of the companies involved in the UCG pilot, Linc Energy, was recently committed for trial in the District Court on five counts of wilfully and unlawfully causing serious environmental harm.

“The investigation of Linc Energy is the largest and most expensive case ever handled by the State‟s environment regulator, the Department of Environment and Heritage Protection (DEHP),” Minister Miles said.

“The Palaszczuk (State) Government has already provided DEHP $15.8M in special funding to deal with this important case. In addition, our new chain of responsibility laws will provide new powers to require that contaminated sites must be cleaned up.”

“Trials have been underway for several years. Cougar Energy‟s trial at Kingaroy was shut down in 2010 after benzene was detected in nearby water bores. Carbon Energy is currently decommissioning and rehabilitating its site at Bloodwood Creek near Dalby.”

4.28 The foregoing highlight the issues alleged and reported as well as those considered of longer term significance, such as decontamination, site clean-up, public reassurance and certainty for the resources industry. It is at least interesting that the issues reported at committal and in potential trial papers were considered sufficient for the government to reach for a ban as the preferred way ahead, in a state with rich resources and a long history of exploitation, not all of which has performed to the highest standards of environment protection or community engagement.

4.29 Shortly after the ban was announced, on 14 May, reported by Reuters, the administrator indicated Linc Energy should be liquidated. On 22 May 2016 Linc Energy‟s creditors voted and administrators acted, based upon their Singapore listed holding entity, to liquidate Linc Energy. The company shifted its listing to Singapore at the end of 2013. At closure borrowings and debts exceeded assets.

4.30 ABC (2016b) reported the view that the company had chosen administration so as to avoid penalties for polluting the environment.

Queensland‟s Environment Minister said this, “was a prime example of why the Government introduced "chain of responsibility" laws in a bid to make it easier to recover the costs of environmental clean-ups if a company crashes. We need better laws to ensure companies can't avoid their environmental obligations," he said.” ABC (2016b)

4.31 Separate legal action was initiated on 10 June 2015 in relation to soil contamination as a result of drilling and sampling identifying the presence of carbon monoxide, hydrogen and hydrogen sulphide in the soil at depths between 2 and 6 metres underground and across an area of over 300 square kilometres. This cautionary zone for any excavation activity, which must be approved now by the Department, remains in place.

4.32 Monitoring of soil continues at and around the site at Hopeland. (QLD DEPH, 2016b). The state Environment and Heritage Department indicated that,

"In June, Linc"s liquidators used Commonwealth (Australian Federal) legislation to „disclaim", among other things, its underground coal gasification site in Hopeland. The Queensland Government has now secured and taken responsibility for the site. The Queensland Government has engaged contractors with expertise in managing petroleum facilities to provide care and maintenance at the site. EHP and the Department of Natural Resources and Mines (DNRM) closely oversee health, safety and environmental matters."

4.33 The department also stated at that time that,

"It is important to note that extensive testing and monitoring has confirmed that the regional air quality remains safe, as does the drinking, stock and underground water supply."

4.34 In the course of this review, I have been made aware of a range of concerning incidents in Australia, the US, South Africa, from the European trials and in China that suggest this industry is still in an early stage of development where hazard management and best practice are not yet fully appreciated or in place. I have been shown and given oral reports, some conforming to media reports, company worker and regulatory staff observations, some of which are captured in FoE and Broad Alliance submissions, interviews and reports, and some of which were shared on the basis that they would not be quoted or localised.

4.35 In general they suggest what the partial or largely absent public reporting hints at: that there has been in most locations worldwide a catalogue of experiences by some if not most operators which demonstrate that they have fallen below the standards of performance in environment and health and safety management that it would be reasonable to expect. Until such data are provided, both allowing full hazard assessment and clearly demonstrating that best practice is understood, possible and can be routinely achieved, it is hard not to conclude that it would not be acceptable or desirable to replicate experience of companies active in recent years elsewhere, in the contemporary Scottish context.

4.36 I fully accept that some operations are in potentially higher hazard, shallower contexts than apply say in the FoF and some operators have better records than others and I acknowledge the ambition and intent as stated of other operators to deliver a best practice performance. The gap however between intent and impact has to be borne firmly in mind when considering the granting of permissions to a fledgling or immature industry without extensive demonstration effort and appropriate safeguarding.

4.37 Summary

At this point, there is no single or comprehensive overview of the environment and health and safety issues relating to UCG. Not least given again the lack of publicly available data, there has not been a desk testing or expert review of such monitoring data or collected materials from operators and regulators, as exists. Shaping policy in detail without a scientific review, perhaps including the HIA-type inputs considered in the Health section, it is difficult to assess from the literature the nature and extent of the issues or to suggest proceeding without significant precaution.

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5. Regulation and Land Use Planning

5.0 This chapter has been prepared following consideration of the literature, materials from and interviews with Scottish Government, SEPA, SNH, HSE, BGS, the Coal Authority, DECC (now DBEIS), Marine Scotland, CoSLA, Falkirk Council, CNRL and a number of commentators.

5.1 The planning and regulatory frameworks for UCG are not explicitly set out but need to be assembled from several components. Planning and regulation facets relate to the preparation for operations, geophysical and environmental testing, drilling and construction phases of UCG as well as operations and closure.

5.2 These relate in detail to access, transport, drilling, licensing of coal related activity, activities impacting the aquatic environment – surface and ground waters, and potential and process releases to the atmosphere, controlled waters and the terrestrial environment including soils, landfill and disposal at sea, the generation and storage of wastes, the storage and transport of hazardous materials, including flammable gases, regulations on radioactive materials including naturally occurring radioactivity, control of major accident hazards, pipelines regulations, planning and development control arrangements relating to operating hours, noise, odour, nuisance and so on. It is complex. Arguably no more so than for other chemicals or oil and gas sector activities but UCG as contemplated in the FoF, for example brings these issues into the overlapping zone of onshore and offshore, closer to populations and connecting with other infrastructure, activities and their services.

5.3 Legislative framing for treatment of UCG is relatively poorly covered in the literature and general planning, mining, oil and gas (petroleum) and environment protection legislation applies in various jurisdictions. Experience in Australia is covered later in the report but the Unconventional roadmap process in South Australia as well as the principles of the trialling model in Queensland are instructive. Kalkbrenner (2014) describes the Canadian context in Alberta but, understandably, she focuses on the legislative components themselves without connection to practical implementation in any detail. Goldstein et al"s work in SA DMITRE (2012) is most likely to allow consideration of good practice and the issues arising.

5.4 DECC set out onshore oil and gas exploration regulation arrangements in DECC (2013) and although the fit with Coal regulation is not always clear, this helps map the edges between the domains.

5.5 SEPA provided a great deal of material on their roles in relation to UCG and CoSLA provide a local authority perspective in their interview and the submissions they made, based on learning from the experience of the Dart Public Inquiry and dealing with a UGE application. Some of SEPA"s materials were provided on the basis of my private use and not for publication and local authority inputs were in part caveated based on the sisting of the public inquiry. All of this, and other information would ideally offer a lot of scope for learning of direct relevance to an appropriate regulatory and planning model.

5.6 SEPA (2012) sets out the principal areas of relevance to UCG for regulation by SEPA, although the document is explicitly addressing shale gas and coal bed methane. These, largely driven by the suite of relevant EU Directives in the environmental acquis, are:

- "The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (CAR)
- Pollution Prevention and Control (PPC)
- The Control of Major Accident Hazards Regulations 1999 (CoMAH)
- Inputs to Planning
- The Environmental Impact Assessment Directive (EIA)
- Environmental Liability (Scotland) Regulations 2009 (ELR)
- The Management of Extractive Waste (Scotland) Regulations 2010
- Waste Management Licensing Regulations
- NORM Radioactive Substances"

[See references at end of chapter for fuller details and links]

To this list would now likely be added at least the provisions of the Industrial Emissions Directive (IED), implemented later in 2012 in the Pollution Prevention and Control (Scotland) Regulations 2012, the revised CoMAH regulations (partially implementing the Seveso III Directive) and the emerging suite of reference documents emerging from hydrocarbon and gas storage Directives and consideration of their fit with the rest of the acquis.

5.7 All of the above appear likely to apply to UCG operations, and in addition, duties connected to gas accounting, including EU-ETS or similar future arrangements might also be in scope. SEPA has assessed preliminarily the potential environmental hazards associated with UCG and also the issues operationally that might increase risk. Possibly most relevant at this stage is the "lack of evidence of environmental impacts from similar situations", both generally, globally and in the FoF context, which confirms my findings, and their view that there is a "lack of clarity about the degree of regulatory control over the UCG regulatory framework". Whilst, I understand, dialogue is ongoing between SEPA, HSE, CA and SG, "because these controls and regulations are still being clarified, it is not possible at this stage to assess the level of protection they provide."

5.8 Scottish Ministers directed SEPA in October 2015, based on the provisions and scope of the Water Environment (Controlled Activities) (Scotland) Regulations 2011, to refer to them, for determination, any application to carry on any controlled activity in relation to UCG. While cores sampling was excluded, any gasification activity fell under the direction. SG (2015)

5.9 Discussion with SNH indicated their view is of UCG being a "relatively untested technology" with a controversial track record. They indicated that proposals would be assessed on their merits and some early discussions with developers had taken place. Reliance would be placed on advice from SEPA, local authorities and Marine Scotland and their interests would substantially relate to protected sites, in the case of the FoF, that SPA. Pathways to impact were noted as being unclear and the priority would be the direct components of obtaining sufficient information to allow an adequate Habitats Regulations Assessment to be concluded. The only issue identified as lying outside the normal regulatory standard was subsidence. The precautionary nature of the Habitats Regulations was also noted. Finally, the observation was made that simplification and clarification of the regulatory framework and effective integration of effort would be welcome.

5.10 Marine Scotland indicated the role of the National Marine Plan and their general policies in framing licences. Currently there is no specific additional guidance for onshore oil and gas activity or UCG specifically. Scotland is divided into 11 regions and the Tay and Forth estuaries are grouped together. There is not currently a Marine Partnership for this area. Generally the view provided was that this was an early stage in the development of arrangements and much remained to be firmed up. Similarly it was agreed that monitoring and reporting issues would need to be tackled in due course.

5.11 HSE set out that, other than the general provisions of the Health and Safety at Work legislation and areas of common interest with SEPA around CoMAH etc, specific terms relate to boreholes and wells. Aspects of these are currently under consideration for amendment, partly to address the possible needs of the UGE industries. UCG is not specifically included at this point but would likely be considered in scope. The specific legislation is the "Borehole sites and operations regulations, 1995 (BSOR)" and "The Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996". There was again a broad agreement that mapping of the components and fit of relevant regulations between the relevant regulators would be desirable.

5.12 Discussion with the EU Commission clarified the view taken that for unconventional gas generally and shale gas/HF specifically the Commission staff believe that exploration is covered by the range of existing EU and national provisions with no significant gaps. See (http://www.europeunconventionalgas.org/environment-and-communities/eu-regulation). BREFs (Best Available Technology/Techniques Reference Documents) are being developed from the 1994 Hydrocarbons Directive to incorporate further UGE aspects. This will be ready during 2018 on current plans.

5.13 The 2014 EU Commission communication on hydrocarbon exploration and production set the scene for much work that is still ongoing, (http://eur-lex.europa.eu/resource.html?uri=cellar:a46647dd-843b-11e3-9b7d-01aa75ed71a1.0001.01/DOC_1&format=PDF) but it is clear that UCG, addressed initially in the 1985 Directive (85/3337/EEC), is not currently a focus of policy attention. Also, research work under Horizon 2020 and the 7th Technology Framework has been taken up largely only in Poland at present and has a hydrogen focus, based on the work at the Barbara mine. (See Annex 3).

5.14 An engineering BREF is also being considered for Waste Management Plans associated with UGE and this would also relate to another process to provide further consideration of the Water Framework Directive and how its requirements might better be addressed in the UGE context. EuroGeoSurveys also observed that as we currently do not have a comprehensive map of UCG, or UGE generally, or agreed terms for definition, or a comprehensive assessment of existing projects or research activity, there is a great deal of work to do, especially if the industry is to progress to allow appropriate policy shaping and information sharing. One of the most relevant recent pieces of work stems from EC (2014), a study of deep underground coal gasification, and this is a major strand of policy work that was a key component of the CCS plans being progressed and considered for funding by the Commission. Current status is less clear.

5.15 Convening a collegiate model process as advocated by RRG from 2006 (http://www.gov.scot/Topics/Business-Industry/support/better-regulation/regulatory-review-group/membership) for tackling new and complex regulatory challenges and doing so in an informed and forgiving environment, involving developers at least in part in the process, would be desirable and help regulators and policy makers greatly in scoping, identifying and ironing out issues for the future and shaping a good, viable model. Use of experts, scenarios and appropriate trialling is essential for such new or challenging issues. The Vannan and Gemmell (2012) model is also relevant as is the approach proposed in Gemmell et al (2016).

5.16 BGS, Jones et al (2004) gave a simple summary of environmental issues for UCG as follows,

"There are some significant environmental issues of the UCG process, including the potential for subsidence, atmospheric emissions, the possible interactions of the UCG cavities with aquifers and the potential for pollutants to migrate away from the cavity (Creedy et al. 2001). Careful site selection and process control are required to control the dispersal of gas and liquid by-products from the gasification cavity, and the configuration must be designed and assessed to minimise ground subsidence. Abatement equipment at surface is used to maintain air emissions (acid gases, particulates and heavy metals) within the Regulatory requirements."

5.17 The Royal Society of Edinburgh made a number of interesting observations too, on the context for regulation of unconventional gas and generally:

"If Scotland decides to source more gas domestically, it would have greater control over the introduction of environmental control measures, such as carbon capture and storage, although such action could see gas prices rise."

And

"Onshore production of unconventional gas would allow Scotland control over all regulation surrounding extraction and production. The impact of unconventional gas production on the environment is considered to be comparable to conventional gas. The areas of health, wellbeing and safety surrounding an onshore industry do not appear to present significant risks, although a degree of uncertainty is present."

And,

"Public opinion relating to onshore unconventional gas development, particularly surrounding safety, in Scotland is often negative and this could make developing an industry difficult."

5.18 A number of assumptions and policy points are embedded here. All seem valid. SEPA‟s duties are a part of this but it appears likely that HSE, Marine Scotland and the local authority as well as SG itself would have an interest in these elements and in the fit between them. BGS and CA would be sources for aspects of the necessary information but also, in CA‟s case, a key player requiring reassurance and demonstration by an applicant that they had been considered adequately and that initial licence terms were being complied with.

5.19 Approach to Licensing

Questions arise, given observations from various regulators and operators as to the coherence, order, fit and primacy of regulator and licensing activity. It is not clear the extent to which this has been considered and agreed by the parties involved. As indicated earlier when considering the Coal Authority‟s initial licensing powers and advice, the CA requires conditional licence holders to discuss issues with DECC (now DBEIS) as well as The Crown Estate (a likely marginal role especially once former constitutional aspects are fully addressed and key responsibilities formally pass to local government), MoD and other "relevant bodies", clarified in interview as including, in Scotland, SEPA, BGS, Marine Scotland, HSE and Scottish Government itself as well as relevant local authorities, prior to issuing a full licence. There would then be the specific requirements of these bodies to address as to the particular permissions they provide. We have not reached the point for UCG where these become "live".

5.20 That brings, however, ten bodies into play in a specific case. In all probability, subject to the details of the applicant developer‟s plans, SNH, for habitats and birds directive purposes and other issues relating to protected sites would also be involved but that would more likely relate to planning and then monitoring phases rather than licensing and operation. If a new water supply issue or significant demand were involved, Scottish Water might be consulted too.

5.21 As to specifically regulatory entities, five bodies plus the local council would be expected routinely to be involved. This complexity was considered by Andrew Nunn of Cluff Natural Resources to be multiple and an issue but manageable, realising that the various components were necessary and the company could deal with it. They did however, as did all of the regulators variously suggest that there was room for simplification and integration to ensure a good fit between the components as well as improved communication between the organisations and regulators involved.

5.22 Planning

Scottish Government, in addition to the SEPA UCG Direction above, issued Directions to planning authorities (unconventional oil and gas and UCG) similarly ensuring a call-in approach. The requirement, in addition to timing detail, to ensure receipt of environment report/statement, assessments concerning conservation, habitats etc., planning documentation concerning transport and noise etc., whilst largely standard, "ensure(s) the Government‟s position on UCG is reflected through the planning decision making process.

5.23 The basic elements of the planning system that relate to UCG arise from The National Planning Framework (SG, 2014) and potentially the strategic framework for critical national infrastructure. If new, nationally important infrastructure is needed (which is subject to planning controls) then the National Planning Framework has been used in the past to designate certain developments as "national developments". Section 6 and Annex A of the NPF provides more information. There is a description on P72 of a CCS development which appears reasonably similar to what would happen for UCG. Any "national development" would need to have full Government backing and its delivery needed in the national interest. http://www.gov.scot/Resource/Doc/346469/0115308.pdf
The first few pages of this document provides an explanation to how SG goes about designating national developments:
http://www.gov.scot/Resource/0042/00420881.pdf

5.24 CoSLA"s submissions to this review process, attached at Annex 2, I-7, substantially advised and influenced by the Heads of Planning and Falkirk Council"s experience of the Dart Public Inquiry (PI), reflect the range of concerns arising from practical experience of the related but different processes involved in considering application for and early operations relating to a Coal Bed Methane project. The Dart PI process has not completed and therefore it is not yet possible to learn all of the lessons of this experience and consider how these might shape UCG policy and licensing. Nonetheless, there are some clear pointers to the likely issues to be considered.

5.25 Issues are raised around the level of resources, the availability of mineral and energy expertise, the skill and time taken to support an applicant and input to inquiry processes and so on. For a small local authority or even a large one, and potentially for SG itself, there are major considerations around costs, capacity and capability in this area. A dedicated approach to centralised or co-ordinated expertise is certainly suggested.

5.26 Vannan and Gemmell (2012) considered the fitness of the existing environment protection regulatory regime to apply to CCS and aspects of that work could inform the treatment of UCG but also suggest a potential model. Especially in the context of points made by Coal Authority, Marine Scotland, SNH, HSE and SEPA, about resource levels, skills and system coherence, a robust model based upon full cost recovery and effective marshalling of available resources is suggested and would beneficially be developed and trialled. Mapping of what is needed and who is best placed to do what and then how and in what order this fits, is shared, executed and then serves to monitor and share progress is well worth considering. Industry concerns about the scale of the burden of regulation can also be handled better by taking a suitably engaged and rounded approach of this kind. (Gemmell and Scott, 2013)

5.27 Whilst potentially unclear or limited to application in England, the role of the Infrastructure Act 2015 and its potential parallels and application in Scotland, may be significant, or at least worthy of consideration, not least in relation to both the pipeline needs and syngas facility but also in relation to air monitoring. Aspects of the Act refer to UGE and HF activities but not UCG and it is not clear how the Act would affect planning and operational conditions, prior to and during the lifetime of a licence for UCG.

5.28 Following interviews with various experts, particularly including the Coal Authority (CA), HSE, SEPA and energy industry economists as well as reading the available Queensland and related literature, I have strong concerns about liabilities. Most industrial operators and the projects pursued and reported to date have not reached the end of the life-cycle, even if they have stopped. Impacts are only partially understood. Monitoring has often been inadequate and there is an easy inference that there has been an approach of "if we don‟t look, we won‟t find".

5.29 Discussions with industry consultants suggests a widespread view that the coal industry, both deep and surface, as well as a number of resource industries globally have not always viewed environmental and community factors as priorities. Similarly, hazards, including interconnecting ones of health and health and safety, have had inadequate provision or have been left to be addressed only when they became a priority, often therefore when impacts had crystallised. Lessons in some cases have been learned. But the establishment of action plans, monitoring programmes, credible bonds and insurances to ensure available resources for remedial action as well as actual planning for reinstatement and detection of issues of concern, for example, is often seemingly left late or best intentions, and even written plans, are trumped by other factors. These would include economic realities, market conditions, encountering unexpected geologic conditions, sudden groundwater condition changes or accidents and so on.

5.30 Especially for a developing or immature industry, I fully accept that making provisions for liabilities is a challenge. When exploration and production are very expensive, infrastructure needs lie on top of this and may be even larger, making full provision for costs, events and remedy that is at least to some extent unknown at the early stages is very difficult. Nonetheless this lies at the heart of understanding the context and the appetite for risk, especially the acceptance of known hazards and real mitigations. Costs of remediation of contaminated ground and groundwaters may cost many times the actual project costs and could and can take decades. The CA and the Queensland state administration appear to accept that some bonds and commitments, for example, have not been (possible to be?) well policed and some operators, as several regulators have said, have not been held robustly to account for failings. These failings and their impacts affected the broad community and environment, sometimes in ways not initially seen or understood. And when needed, funds were not available, nor were data, and the public bodies and purse were left to pick up the bill. This would not appear to be wise to allow to be repeated. This in turn places even greater focus on strong and simple regulation as well as on very good ex ante assessments and robust licences, with very strong oversight during and following any project.

5.31 Summary

Several players are involved in the regulatory space and arguably too many. Individual elements are dedicated to specific understandable purposes. To be effective and certainly to be efficient, they would benefit from detailed role, needs and task mapping, consideration of simplification and testing of how they would operate best and most effectively for the operator/applicant and for the public purse as well as in order to ensure delivery of the individual and joint policy objectives. The systems involved do not appear at this point to offer a fit-for-purpose, best practice or even tried and tested overall approach. It is recommended that there be a clarification of roles, fit and ultimately primacy in setting requirements, making decisions and taking responsibility overall for client management and the overall judgements required.

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https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/265984/Onshore_UK_oil_and_gas_exploration_Scotland_Dec13_contents.pdf

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- The Control of Major Accident Hazards Regulations 1999 (CoMAH)

  http://www.legislation.gov.uk/uksi/1999/743/contents/made

Now the Control of Major Accident Hazards Regulations 2015 (CoMAH)
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6. Health

6.0 Health issues appear to be the least well represented in the available literature in terms of actual health impacts from UGE. Inputs were therefore sought from Health Protection Scotland, the academic community involved in public health as well as industry specialists here, in Australia and worldwide. This helped to clarify the likely needs for assessing health issues in future.

6.1 Details of impacts at this point appear largely anecdotal. Public health requirements and performance data are very weakly covered in the accessible literature about UCG. Tuller (2015) observed that there was a dearth of health risk data (still) despite the rapid progress of fracking activity in North America. There appears to be even less material in relation to UCG.

6.2 Watterson and Dinan (2015) address the issue of Health Impact Assessments (HIAs) in the context of the unconventional gas industry in the UK. The focus, again, understandably is on method and potential value but there is very little direct content connected to or directly relevant to UCG. The authors do discuss the results of a number of community surveys in the UK context which give particular prominence to the issues of "fear, anxiety and stress" associated with those attending workshops where UGE activity was under consideration in their communities. The paper also communicates very effectively the issues around ensuring robust science is applied to HIAs and a professional process and skilled oversight engaged to ascertain and support communities going through the experience of dealing with a UGE proposal.

6.3 Guidelines produced for UKOOG by Andrew Buroni and colleagues are also especially relevant. UKOOG (2015). The literature review conducted for the report,

"established a list of potential hazards associated with international onshore oil and gas, including:

- Emissions to air
- Potential health risk from exposure to combustion emissions: Particulate Matter (PM10 PM2.5) Nitrogen Dioxide (NO2) Sulphur Dioxide (SO2), Volatile Organic Compounds (VOCs), benzene, toluene, ethylbenzene, and xylenes (BTEX) and Radon;
- Potential health risk from exposure to fugitive emissions: methane, VOCs/BTEX, dust and odour;
- Noise: potential impact on annoyance, sleep disturbance, impacts on academic performance, stress and anxiety;
- Traffic: potential risk of community severance, congestion, risk of accident and injury, changes in air quality and noise exposure;
- Visual impacts: potential risk of reduced amenity value and enjoyment, stress and anxiety;
- Emissions to surface water: potential risk of contamination (spillage risk of hydraulic fracture fluids, drilling muds and site materials) and potential entry into food chain;
- Emissions to ground water: potential risk of contamination (fluids, drilling muds and flowback) and potential entry into food chain;

- Water availability: potential risk of reduced public access to ground water (i.e. local extraction where a centralised water system doesn‟t exist);
- Induced seismicity: potential risk of injury;
- Waste: risk from exposure to NORM/radon and pollutants of concern;
- Fire / explosion: potential risk associated with the production, use or storage of any combustible or explosive compounds;
- Construction and occupational hazards;
- Socio-economic: potential risk to tourism, farming, house prices, income and employment;
- Socio-cultural: risk of crime, substance abuse and change in local service and amenity demand;
- Psychological: risk perceptions, fear, stress and anxiety. "

6.4 The report acknowledges that several of these relate to other industries but the work seeks to assess these issues and consider the "sources, pathways and receptors" model that would make these real health hazards. The material is informative and relevant and seems eminently sensible to apply to UCG. This does not yet appear to have been done.

6.5 In Australia, where again there is a somewhat richer literature, but still a focus on generic health hazard dimensions and process dominating over detailed content, the issues relating to health and energy use are set out by Armstrong and Tait (2014). They address the range of inputs to human health including mental disorders. The authors also state that "Greenhouse gas emissions arising from the energy sector in Australia and globally are among the most powerful drivers of climate change. Climate change has been described…in The Lancet as „the biggest threat to human health of the 21st century‟ (Costello et al., 2009) and is already contributing to increased global morbidity and mortality, with Australia amongst the most vulnerable of all developed countries. (Hughes and McMichael, 2011)

6.6 Although a number of unconventional gas issues are covered there is only a brief mention explicitly on UCG, referring to "proven…risk….to water quality in Australia, with pilot projects shut down in Queensland following the appearance of benzene and toluene in bore water", but it is another useful contextual primer.

6.7 Whilst a search of CSIRO and NHMRC records revealed a number of health studies and framework assessments for CSG and HF technologies (see references for this chapter), there was no record found of UCG studies. Some of the studies were interesting and potentially make points of relevance, for example, ERM (2013).

6.8 This apparent lack of UCG health data is unfortunate in that the claims by industry and advocates that the technology can be operated safely, protecting the environment and public and worker health, would be much more credible were these data to be freely and widely available. Their absence, given the number of trials, demonstrations and operational sites worldwide is at best unfortunate.

6.9 Virtually all UCG sites considered appear to have histories involving environmental and/or health and safety incidents, as indicated in earlier chapters. The detail of these histories is very challenging to assess objectively as the literature and media coverage appear to be based on anecdote rather than objective study.

Daily Telegraph (2016) for example. Neither companies nor regulators appear to have provided detailed reports of performance against licence or best practice considerations or to have set the local community context. It is of course reasonable to take the view that responsibility here could lie with national and local government to have constructed health baselines appropriate for subsequent consideration of the performance and impact of an industry in that area. In any event, such data baselines and longitudinal data sets seem either not to exist or to be very rare.

6.10 Information provided by the Chief Scientist in New South Wales (NSW) is also of interest. Although it focusses primarily on CSG in NSW, it also includes UCG information. (NTN 2013). The observations on impacts are of some concern and highlight some of the challenges in identifying and monitoring impacts in complex contexts.

6.11 The most recently reported and, albeit to a limited extent, documented, impacts also come from Australian operations, in Queensland. Linc Energy"s Chinchilla operations on the Darling Downs, see Annex 3, are initially addressed through the terms published by the Queensland government for Linc"s EIS. See Linc (2007).

6.12 On the basis of this limited available evidence, performance is not easily seen as transparently positive, confidently understood or openly shared and considered. Equally there is little to allow us to see UCG as being different from oil and gas exploration and production generally or other related industrial fields especially in their early stages of development, and e.g. relatively high hazard with a great deal of experience of mitigating actions to reduce the residual risk but with unexpected pressure build-ups, losses of containment, gas releases, explosions, tank and bund failures, surface and groundwater pollution, liquid and solid waste management issues, transport failures, etc. known to occur. Some near-surface operations have had subsidence as well as gas and liquid release issues. There have also been clear cases of worker and neighbour complaints and presentations of breathing difficulties and both eye and skin irritations.

6.13 No rigorous HIA appears to exist in any active UCG location and no longitudinal data were found, nor, beyond the scoping of environmental statements and EIAs, has an ex ante HIA been undertaken to ensure all relevant health issues had been taken into account. Therefore ex post or interim assessments that could be interpreted for suitable learning around mitigation and management, also, do not exist. Confirmation of this situation was sought and received from Professor Andrew Watterson, Dr Martin Birley, Dr Martin Buroni and confirmed by a number of other researchers and public health doctors in the field.

6.14 Ultimately, were the technology to be deployed in Scotland, it would be desirable to move from a position of absence of evidence of impacts (either way) to one of robust evidence of absence.

6.15 Observations on information gaps and needs.

Bridging the gap between evidence and policy is perfectly feasible and there is abundant expertise available, including an active and helpful HIA network and guidance on approach and methods in the literature. As indicated above, air, water and waste related impacts as well as transport, noise, light effects and the psychological impacts from stress, etc. would be in scope for consideration in an HIA.

6.16 At this point a baseline assessment is needed and a full understanding of the nature, range and extent of issues to be considered would be beneficial.

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7. Community and Public Interests

7.0 Establishing community views of UCG is challenging. No detailed surveys have been conducted nor is the "community" itself easy to delineate and interrogate. Establishing what the community understands of, and "thinks about" UGE technologies and practices and separating out the specific UCG component, assumes a widespread provision of information and that having been well assimilated.

7.1 Community interests in and views of UCG are assembled here from interviewing the Broad Alliance, and their submission to me, from discussions and interview with CoSLA and Falkirk Council officers, from a literature and media search, from views shared by local activists with FoE and me and reported by them and from consideration of inputs to related activities such as the Dart Public Enquiry. The submission from the Broad Alliance is at Annex 2.

7.2 To obtain some context, a search was made of UGE more generally in relation to public engagement. Assessments of public attitudes to unconventional gas extraction are still few but the UK shale study by Whitmarsh et al (2015) is instructive. The study revealed significant ambivalence but also highlighted a perception of more risks than benefits. The study"s conclusions continue,

> "the public is highly heterogeneous in relation to shale gas attitudes: prior knowledge appears to be associated with more favourable attitudes, although demographics and environmental values are overall strongest influences on perceptions. Recognising this heterogeneity is important for effective engagement with different audiences; for example, those with strong pro-environmental values are likely to be difficult to persuade of the benefits of shale gas unless shale gas can be successfully framed as relatively environmentally benign.
>
> "…providing information about a particular benefit (economic or environment) of shale gas in general made attitudes more positive, particularly amongst those who are the most ambivalent. It is this undecided group who will be most susceptible to persuasive information, be this from pro- or anti-fracking sources."

7.3 Shackley et al (2004), produced some of the earliest and most informative work on public perception of UCG. The Tyndall Centre study was in the Silverdale area of Staffordshire, conducted in 2003. There is a great deal of detail in the report and I have chosen to extract an extensive part of the summary here. The authors set the scene,

"One of the uncertainties affecting the potential use of Underground Coal Gasification (UCG) is the potential for public opposition to emerge. A proposed trial project in Silverdale, close to Stoke-on- Trent, elicited negative public reactions and was subsequently abandoned. This is despite the fact that the actual proposal related only to the initial drilling stages."

7.4 The situation locally was complicated by challenges to the authority of CA, the role of DTI and the closure of the local mine. The authors state that as a one-off proposal at a preliminary/ pilot stage was not representative of other cases generally. However, the project proposal surfaced issues around a lack of perceived need, concerns for safety, environmental impacts, etc. A focus group was set up and views elicited. The methods involved are described, views presented and suggestions made on how such processes of engagement could be developed and utilised in future.

7.5 The report goes on: "All of the focus group participants recognised the potential of UCG as a secure source of energy for the UK in the years to come, so long as it is safe to human health and the environment and cost effective. It was recognised that there could also be net economic benefits to be reaped if the UK comes to acquire a technical mastery of the process and can export the technology overseas. However, there were also substantial concerns regarding UCG. All of the group members agreed that in its present state any UCG trial site or commercial site situated nearby a local community seems to provide no advantages to the locale but puts the inhabitants at potential risk of industrial hazards. Many communities would feel like a „guinea pig" if it were to accept being part of a trial. It was therefore concluded that future trial tests should be conducted in more remote areas. This finding reflects very closely the findings of the literature on siting of potentially hazardous sites, and the experience of the Silverdale case.

7.6 "A major problem with UCG is that the public would probably perceive it as a high-risk system that has the potential for deleterious effects in terms of health and safety to the local community. There is a general feeling in the focus group that fire hazards and explosions could easily occur and that there is potential for environmental degradation. The high level of concern arises from the perceived lack of control of a combustion process occurring underground and from the perception of a high level of uncertainty concerning the potential hazards. Operators, authorities and governmental regulatory bodies are faced with the challenge of providing evidence of the risks, as well as constructing a due process for making decisions, that will help to build trust in the technology with local communities.

7.7 "With regard to its environmental performance, UCG was criticised in that it is still burning fossil fuel, which does not seem in accordance with low-carbon energy systems. Although a feasible option would be to capture the CO_2 and store it underground (not necessarily close to the UCG extraction site) this still presents the problem for some of the focus group participants of linking together two controversial, not fully tested and potentially dangerous technologies. Overall, it was felt by this group that UCG should only be considered in combination with carbon capture and storage (CCS). Several participants of the focus group favoured further development of UCG until it is a ready-to-use technology, but that it should only be implemented on a large scale if other energy supplies fail; i.e. UCG should be viewed (according to these members of the group) primarily as a potential back-stop technology.

7.8 "UCG was still viewed by most members of the group as a good energy safety net for the UK and several suggestions were made as to how to improve its public perception and integrate it more closely within a sustainable energy programme. First of all one must overcome the public"s lack of confidence towards developers, operators and regulators. The main mechanism suggested to achieve this was through greater transparency of operations and clear information regarding the day-to-day processes, safety measures and environmental impacts of the UCG plant. This could be done through:

- Creating an information/community centre where people can easily inform themselves and ask questions. Up-to-date information on operations and plans would be made available. This could be complemented by occasional public events by regulatory and operational bodies and open days where the public could access the plant.

- Providing a budget to the local community so they can employ independent reviewers and experts in order to cross-examine all data and ensure good practice and conduct of operations. In this way, the local community would have greater confidence in the regulatory process and underlying data thus improving mutual trust.

- Getting the media to advertise such collaborative schemes and to provide a publication avenue for information and developments.

- Providing a written statement regarding the responsibilities, duties and liabilities to be undertaken by each responsible party in the event of an incident. Secondly, UCG should be presented to the community within a package of improvement measures such as:

    - Combining UCG with other, more labour intensive industrial developments as part of an employment initiative, or else with local regeneration schemes. This might involve energy sector developments, such as a UCG Technology Centre or development of local industry based on UCG gas for heating and chemical production.

    - Producing hydrogen from the product gas, which could be used to kick-start a local hydrogen economy scheme such as providing the fuel for town buses. This could then provide environmental benefits as well as helping the area become a pioneer of hydrogen technology and infrastructure.

7.9 "This project was a pilot stage investigation, which made use of an existing group that had prior knowledge of, and discussions about, climate change and of carbon capture and storage. This is likely to have influenced the perceptions of the group regarding the role of UCG in the UK‟s energy system. Furthermore, the composition of the group was not at all representative of the British public. Further research could involve holding more focus groups with a wider cross-section of the public in terms of: gender, socio-economic group (occupation), age, place of residence, psychographic profile, etc. A further activity might involve conducting face-to-face surveys with a larger sample of the public." Shackley et al (2004)

7.10 The report concludes, "If a specific proposal for a UCG demonstration site is being considered, a „citizen panel‟ consisting of a cross-section of the public in the locale might be constituted in order to provide advice on how a proposal should be developed. The local public and stakeholder reaction should be part of site selection process, alongside the more tangible issues such as coal geology, hydrogeology and other planning issues. Other possibilities for the future could include: development of a professional communication strategy, before any trial site is selected, setting up of an information web site, and the production of other suitable publications."

7.11 Many of the issues, perceptions and attitudes reported and suggested in the Silverdale Study align with views presented a decade and more later by community representatives in Scotland and this is reflected in the submission of the Broad Alliance at Annex 2. A lack of confidence in operators, regulators and government was evident in discussion and the situation is more complicated as a result of knowledge of former mining, even if active coal mining is now more distant in time, impacts being even less certain as well as the sub-estuarine context, the historic lack of consultation or engagement about projects likely to influence the community and its environment, as well as increased awareness of climate imperatives and the performance of the industry internationally.

7.12 There is no similar work from the Scottish context but studies appear to have been undertaken with sociological, psychological and other health objectives. It would be highly desirable to collate and expand this work as well as obtaining baseline data on perceptions in this context.

7.13 Within the National Planning Framework discussed earlier, there are objectives for land-use planning that makes Scotland "a low carbon place", with an ambition that we have greater "wellbeing and opportunity", and with "increase(d) solidarity". Community planning is also highlighted. The ways in which the planning system will deliver this and how the public generally and specific local communities in particular, might be more fully engaged in consideration of significant infrastructure, is not clearly spelled out. Using existing planning processes, up to and including Public Inquiries, planning appeals and call-in mechanisms connected to representations and petitions, etc. would all be considered in scope. It raises the question of whether this is sufficient and if or how this could be done better.

7.14 A particular challenge is in identifying "the community". In the case of a project under the FoF, what and where is the community? What is local? Which community? Gasified coal panels somewhere under the Firth wouldn"t have a community over them. In some respects the whole estuary area and communities on both sides of the river would be in scope. More likely perhaps the notion and framing of community might rather relate to those closest to, or surrounding, the onshore syngas facility and not the sub-marine, sub-estuarine site itself. However, those along a pipeline route, a further processing facility or geologically connected to hazards of seismicity, or groundwater, air quality, light, vibration, noise or transport issues might be justifiably included. It is a question to consider.

7.15 Consideration too might be given to how a community engages or agrees to be involved. It might be that consideration of the potential use of a voluntarism approach and the lessons learned from the UK Committee on Radioactive Waste Management"s (CoRWM) public consultation approach both generally and around the West Cumbria casework would also be beneficial (DEFRA, 2006 and later DECC published materials from CoRWM). CoRWM has engaged widely in challenging circumstances but has also looked at public engagement, planning processes and delivering longer-term challenges on the basis of a partnership between the implementer and the community in France, Sweden and Finland, is exploring this in the UK context and also recently provided advice to the Australian Nuclear Fuel Royal Commission.

7.16 Whilst clearly not the same as radioactive wastes, UCG presents challenges to the status quo at community level and if imposed (as perceived) rather than embraced, difficulties are likely to be considerable given the evidence considered. It would be advisable for there to be careful consideration of lessons that can be learned about using long term approaches; establishing public positions and concerns, engaging communities and ensuring they are best able to be informed, take informed decisions and share in the development, custody and benefits of a local activity. These issues seem to remain areas of real challenge and opportunity.

7.17 An additional consideration, to some extent framing any issues around regulation, industry performance, energy policy, etc. is the question, “Does a General Social Licence to operate exist?”, through what is essentially a moral and ethical position assessment. Is it right to exploit UCG and further carbon from coal or to impose a balance of costs and benefits such that it is possible for a perception to be broadcast that private benefits are being set against public (social/environmental etc.) costs without explicit public support or consent? If, however temporarily, the trajectory of decarbonisation or carbon exploitation were seen to be being reversed, would compensations be sufficient to support the case?

7.18 The UK government has proposed a fund to support communities where UGE progresses in England. Community trusts for some renewables exist in Scotland and have proved beneficial for community developments ensuring a flow of benefits from energy projects.

7.19 A further question exists around the distribution of costs and benefits. Without CCS, UCG would likely be a net contributor of GHGs. Progressing without it would make the Scottish and global impacts greater. Not managing liabilities effectively would leave Scotland and the community exposed to negative impacts. Generally these raise issues of morality and of fairness. Similarly, how is engagement achieved? Is demonstrable support actually required? Planning process and the policy of the day would give projects a permissive or oppositional context. Voluntarism would more likely ensure consent of a community. The levels of opposition seen around the Hands Across the Forth and Frack Off events in 2015 as well as earlier around the Dart CBM project at Airth simply serve to highlight the challenge.

7.20 The Broad Alliance submission at Annex 2, Concerned Communities of Falkirk reports (2014, 2015) and FoES (2015) as well as FoEI (2016) raise a range of issues about community concerns.

7.21 Contextualising and summarising these through the Broad Alliance Submission, these concerns appear to be as follows:

- UCG will have a negative impact on climate targets for Scotland, especially without CCS
- The industry has a poor reputation and has performed poorly worldwide

- Kincardine and FoF generally are unsuitable areas for licensing UCG not least on the basis of the geological conditions, history and information inadequacies
- Earthquake risks are considered serious and uncertain
- Environmental and health and safety impacts of tests worldwide are negative and plainly damaging, although poorly documented and could affect communities and workers
- Regulators do not have the tools or the staff to do the job properly, including the licensing and monitoring work needed
- Operators have stated operations are safe and will not cause damage but information available, including legal cases, contradicts this and raises concern and doubt
- If it has been banned in Queensland, why is it acceptable here?
- BA has no confidence that community views will be adequately considered in any specific application
- Economic opportunities are believed to be seriously overstated
- If UCG progresses it will damage the reputation of affected areas, their economic wellbeing and scope for green investment

7.22 These issues are understandable and at least in part supported by the evidence available. It seems reasonable to consider that all ought essentially to be taken seriously and addressed with specific responses based upon robust interpretations of the evidence, connected to new or publicised existing performance data and other relevant evidence, together set against a stance of reasonable precaution.

7.23 The views represented are strongly held and suggest sufficiently deeply rooted negative attitudes that no short-term dramatic improvement seems likely.

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And linked documents assessing the French, Swedish, Finish and other experience in public engagement and voluntarism.
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8. Climate

8.0 Climate issues set a key part of the global context for UCG as well as framing the connection between GHGs generally and the local emissions and products of the process. Inputs to this chapter come from the academic literature, academic interviewees, the CCC and informed commentators.

8.1 This report does not, and cannot, seek to provide an overview of global and European climate science or even of the UK climate and carbon position in any detail. Contextual reports and assessments can be found in the work of the Intergovernmental Panel on Climate Change (IPCC), in Hansen et al (2013), and an instructive paper by McGlade and Ekins (2015).

8.2 UCG processes are predicated on the partial conversion and effective oxidation of carbon in the coal, with addition of air or oxygen and steam, to methane. Combustion with oxygen produces "product gas" which is methane, with associated carbon dioxide, CO_2, carbon monoxide, CO and hydrogen (H_2) as well as combustion products derived from the impurities in the coal. Combustion with air, adds significant nitrogen to the gas product mix. From the point of the release of these gases, through their transmission to the surface and during their subsequent processing, separation and distribution, they can and will be released to the atmosphere. Some of this is intended through its use (methane for gas supply and industrial use for example will be released post secondary combustion or processing if not locked into new chemistries/products), results from flaring or "controlled" releases and some will be fugitive (leaks) and/or as a result of incidents of loss of control. These gases if not locked into new materials or stores for the long term, will contribute to the greenhouse gas (GHG) load of the atmosphere which is in turn causing climate change effects.

8.3 The whole picture of the stocks and flows of carbon on the Earth, while well understood generally, is not fully understood at a detailed and localised level. The many components of the geology and soils beneath us, the oceans around us, the biosphere of the planet and the human communities living within this context as well as the atmosphere around and over it, are still being studied. The subject in itself is an area of emergent science, with many elements not yet fully understood or quantified. Understanding the exchanges over time between the various parts of the system is complex. Gas use and market development sit in that context. Understanding the scale, significance, inputs and impacts, of individual industries, such as UCG, and the processes involved is often problematic and uncertain, compounded by data availability.

8.4 Fugitive impacts in particular are hard to assess when we have rarely measured what is emergent from the soil and surface water bodies, former mines and other possible sources and hence contextualizing new extraction is challenging. Also, as will be touched on in the energy policy chapter, much depends on whether UCG gas would substitute for other gas. An arguable advantage of UCG methane and hydrogen could be their local production and hence availability and their local use, both potentially stimulating new markets, serving existing ones and minimising transport impacts and use of imports. What happens to the carbon dioxide remains a key question.

8.5 On top of these factors, is added the nature of UCG gas – the main elements and mixtures were addressed in the Geology and Technology chapters earlier and some results shared suggest the gas produced is more complex or "dirty" than gas sourced from some reservoirs in the North Sea. This means subsequent processing, cleaning, would be required with extra energy inputs to ensure separation into purer usable ingredients. This technology is well-developed and deployable. Overall the impact the gas has will be determined by its composition, the volumes generated and how it is used.

8.6 The UK Committee on Climate Change (CCC) has not offered an opinion on UCG specifically but has regularly provided a view on climate change issues for the UK as a whole, as well as a commentary for Scotland, as part of UK and devolved administration climate policy implementation, carbon budget and target reporting arrangements.

8.7 CCC Report 2016

"Shale gas exploitation by fracking on a significant scale is not compatible with the UK‟s climate change targets unless three key tests are met – on methane leaks, gas consumption and carbon budgets." This was the headline result of the July 7 2016 Report of the CCC on onshore petroleum in conjunction with their latest carbon budget. Whilst dealing with onshore gas, in the UK context and given its remit, the CCC‟s findings are relevant because they frame the production of gas in a climate change setting that is just as relevant to UCG.

8.8 The CCC website expands, "The Committee‟s report „The compatibility of UK onshore petroleum with meeting the UK‟s carbon budgets‟ is the result of a new duty under the Infrastructure Act 2015. This duty requires the CCC to advise the UK Secretary of State for Energy and Climate Change about the implications of exploitation of onshore petroleum, including shale gas, for meeting UK carbon budgets."

8.9 The CCC‟s report finds that the implications of UK shale gas exploitation for greenhouse gas emissions are subject to considerable uncertainty – from the size of any future industry to the potential emissions footprint of shale gas production. It also finds that exploitation of shale gas on a significant scale is not compatible with UK carbon budgets, or the 2050 commitment to reduce emissions by at least 80%, unless three tests are satisfied:

> 8.9.1 "Emissions must be strictly limited during shale gas development, production and well decommissioning. This requires tight regulation, close monitoring of emissions, and rapid action to address methane leaks.
> 8.9.2 Overall gas consumption must remain in line with UK carbon budgets. The production of UK shale gas must displace imports, rather than increase gas consumption.
> 8.9.3 Emissions from shale gas production must be accommodated within UK carbon budgets. Emissions from shale exploitation will need to be offset by emissions reductions in other areas of the economy to ensure UK carbon budgets are met.

8.10 "At this early stage, it is not possible to know whether the tests will be met easily or not. The Committee will closely monitor steps taken by Government and other relevant agencies to satisfy these tests. The Committee will report publicly on performance against the tests. In addition, the Committee will assess the Government‟s forthcoming Emissions Reduction Plan – which will set out how the Government will meet the fourth and fifth carbon budgets – in light of the possible development of a UK shale gas industry."

8.11 Professor Jim Skea, a member of the Committee on Climate Change, said: "Under best practice, UK shale gas may have a lower carbon footprint than much of the gas that we import. However, gas is a fossil fuel wherever it comes from and is not a low-carbon option, unless combined with carbon capture and storage. This report sets out the tests that must be met for shale gas development to be consistent with UK carbon budgets. Existing uncertainties over the nature of the exploitable shale gas resource and the potential size of a UK industry make it impossible to know how difficult it will be to meet the tests. Clarification of the regulation of the sector will also be needed. The Committee on Climate Change will provide ongoing, independent assessment of whether these tests are being met."‟

8.12 Professor Skea was also interviewed for this study, tapping into his climate and energy expertise as well as his CCC role. See Annex 2.

8.13 The CCC has produced a Scottish emissions picture, a 2015 progress report as well as views of the trajectory to 2030 and "the high ambition pathway towards a low-carbon economy" are all accessible on the CCC website. https://www.theccc.org.uk/countries/country-scotland/. These do not particularly address UCG.

8.14 Bond et al (2014) undertook a life-cycle assessment (LCA) of GHG emissions from unconventional gas in Scotland. The study responded to SEPA‟s observations in 2012 (SEPA, 2012) that "there is a lack of real field data (on greenhouse gas emissions)" and noted that, "different assertions exist as to the extent of fugitive emissions of methane during shale gas operations compared, for example, to conventional gas extraction. Until this dispute is resolved by collection and analysis of actual data SEPA will remain neutral but requires operators to make full use of technologies that capture the gas prior to escape in order to reduce fugitive methane emissions."

8.15 Whilst this work focussed on Shale Gas and CBM, both the principle of collection of, and accounting for, fugitive methane as well as the overall approach to and review of direct and indirect GHG dimensions of unconventional gas activities are extremely useful.

8.16 Addressing UCG specifically, FoES, WWF and RSPB as well as the Broad Alliance, all interviewed for this review, also raised the issue of the principle of compatibility of UCG and GHG production. They also raised the risks of leaks and fugitive emissions generally from this, further proposed generation and release of GHGs and its poor fit with Scotland‟s existing climate commitments and approach to decarbonisation of the economy generally. Permitting UCG was seen as wholly incompatible and contradictory.

8.17 Estimates of gas production are very hard to find and crude assessments are the best that can be done, but the context is extremely clear and well known. As introduced above, Hansen et al (2013), McGlade and Ekins (2015) and the work of the Intergovernmental Panel on Climate Change (IPCC) generally set the scene globally and lead to a general conclusion that a strong case can be made for not progressing with further generation of atmospheric CO_2 and methane given their known impacts and the budgets of these gases remaining if damaging impacts are to be minimised or avoided.

8.18 Hansen et al (2013) provide an analysis that suggests existing, conventional coal resources amount to c.860Bt. A further 1600Bt CO_2 could be produced from new/unconventional exploitation methods, including UCG, Coal Bed Methane (CBM) etc. If all existing conventional reserves were burned this would contribute c.500Gt of carbon emissions, essentially the equivalent of the whole planetary carbon budget since the start of the industrial revolution. [This is c 370 Gt C by 2013 and c 130Gt left – 477Gt of CO_2. An additional c100Gt C exists locked for now in the biosphere.] Their estimate of only 130Gt would remain before breaching a 1.5°C threshold is salutary. Emissions therefore need to be limited to a maximum of 656 Gt CO_2 for 2007-49 based on the assumptions made. This analysis appears broadly supported. Budgets can be constructed on that basis.

8.19 In the Scottish context, the CCC (2016) reports describe the progress already made in Scotland in terms of carbon reductions and Bond et al (2014) attempt to describe the place of UGE in that context. At best, impacts are uncertain. The Belltree Group (2014) Kincardine Feasibility Study, which looked at the resource in that one licence block, one of the two still "in play" in the FoF, the mid-range estimate of accessible coal was 43Mt, the rough equivalent, if all gasified and used for electricity generation, of 120Mt of CO_2. That is around three times the total of Scottish emissions or roughly 18 years of the equivalent prior operation of Longannet. Whilst the full exploitation of this resource under demonstration or operational panels may be unlikely, especially in the short to medium term, it gives a sense of the potential impact.

8.20 FoES suggested that it would be "absolutely irresponsible" to pursue a new source of fossil fuels or access high carbon coal reserves previously inaccessible and a "huge distraction" from the necessary decarbonisation mission. They also highlighted issues of fairness and equity in relation to developing nations and particularly low-lying countries worldwide.
(https://www.foe.co.uk/sites/default/files/downloads/uks-fair-share-emissions-cuts-76425.pdf)

8.21 In interview, FoE also critically observed that, given the timetable likely to apply to getting a demonstration facility operational and progressing to full scale operations, including planning and other processes entailed, it was in their view unlikely that such an operation would be able to be in place within 10-15 years, by which time the Scottish economy would need to be wholly decarbonised. "It therefore simply doesn"t stack up. UCG has no place."

8.22 Pfeiffer et al‟s (2016) analysis also highlights the dangers of lock in and stranding of assets if the zero carbon targets necessary (post c.2017 if the carbon budget ceiling has already been reached, following the IPCC AR5 pathway), are taken seriously in future.

8.23 Bond et al‟s (2014) work is unusual in that it took a life-cycle approach and it concluded that methane and other GHG emissions could occur during drilling and production and from fugitive sources but that emissions per unit of energy generated by UGE are "likely to be equivalent to those from conventional gas extraction in Europe if best practice is followed" and peat soils/habitats are avoided.

8.24 Gas from controlled processes as well as fugitive emissions are generally assumed by industry, although data are very hard to obtain, especially for the latter. Releases by regulated facilities would be expected to be included in licence terms, compliance reports and in national gas inventories under UK (and currently EU), US and Australian law, for example. When asked, Australian commentators observed that GHG impacts and actual releases, especially fugitive losses were not generally considered a priority. As in the EU model, in Australia, total emissions reporting would be undertaken and would connect local regulated emissions to that total. At this point, data on gas total emissions are not widely available, shared or used.

8.25 Carbon capture and storage (CCS) or other effective sequestration methods to offset carbon emissions were discussed with most interviewees. Profs. Haszeldene, Russell, Shipton, Skea and Younger all observed that deployment of carbon capture technology would radically affect the approach taken to the emissions of all UGE including UCG. None of those interviewed considered there to be any realistic prospect now or for the foreseeable future of a CCS investment being made and particularly at a scale and with a timetable likely to allow a neutral trajectory to be achieved, with current emissions or in the context of UGE. No other sequestration method appears likely to make a relevant contribution in this context and in the shorter term.

8.26 Summary

Climate change and decarbonisation targets would be very seriously impacted by unmitigated releases of UCG GHGs if operated at scale, making the achievement of current or stronger commitments much more difficult if not impossible. Without CCS or similar sequestration or storage options in place, while demonstration plant might have a minor impact in the longer term, full scale operation exploiting the scale of the resource available would be potentially very damaging both in fact and reputationally. Thus, even given the uncertainties around substitution or actual levels of final emissions, controlled or fugitive, it is very hard to conclude that UCG is viable in carbon budget or climate change terms. With CCS, fixed in long term reservoirs or fixed in new materials or wholly offsetting imports, the impact would be less unfavourable.

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9. Energy Policy

9.0 Placing all energy policy in context is assisted by reading MacKay (2009). Also, “clean coal” in future energy mixes is addressed there. The phrase itself challenges some in the energy policy community.

9.1 The then Minister for Enterprise and Energy, Fergus Ewing said in a statement to Parliament on 15 March 2016,

“Three things must be achieved. First, there must be a stable, managed energy transition. We must ensure that Scotland has secure and affordable energy supplies in future decades as we address the need to decarbonise our energy system in line with this Parliament‟s Climate Change (Scotland) Act 2009. The Scottish Government must also continue to support innovation and expertise from our oil and gas industry, the deployment of renewable energy technologies and the development of more innovative and low-cost ways of producing, storing and transmitting energy.

9.2 “Secondly, we must take a whole-system view of the challenge. By that, I mean that there must be consideration of Scotland‟s energy supply and energy consumption as equal priorities; we must also build a genuinely integrated approach to power, transport and heat. Our success rests on continuing our good work to make our homes, workplaces and vehicles more energy efficient and more affordable to run.

9.3 “Thirdly, we must embrace a truly local vision of energy provision by promoting local energy solutions, planned with community involvement and offering community ownership of energy generation, and by delivering a lasting economic asset to communities in every part of Scotland.”

9.4 Renewables continue to develop, albeit now at a slower rate potentially, after UK policy changes. It also has to be acknowledged that in the last two years alone the overall context has changed as a result of the closure of Longannet, the extension of nuclear station operational lives at Hunterston and Torness and the termination of the CCS competition process for Scotland generally and for Peterhead specifically. Nonetheless, there is a continuing need for baseload and fully capable and flexible supply inputs that currently are made up of gas, nuclear and other UK and interconnector supply components. As a transition fuel, gas has a significant place, in addition to its relevance for the chemicals and connected sectors. How long that is or will be the case, is unclear but dependent at least to some extent on decisions that arguably have to be addressed now. These would include the renewables sector but also potential UGE and UCG specifically.

9.5 It is not the purpose of this report to provide a deep critique of EU, UK or Scottish energy policy dimensions but it is relevant, in the context of the gas fraction, and for the future of UCG to consider where its contribution would fit and what frames this.

9.6 The overall position for the UK is set out in DECC (2015) and that for Scotland is set out in further detail in SG (2016), where energy use and developments for the previous and current year and overall are presented alongside an overview of the policy position.

9.7 This states that,

“The Scottish Government has identified three core themes, drawing on the emerging consensus concerning the future of energy systems worldwide, building on our current strengths, and the intention to develop an integrated approach to energy in Scotland:

1) Decarbonisation of the energy system by 2050, in line with our long-term climate change targets – producing advice on optimal pathways to maximise economic and social return to Scotland.

2) A whole system view; and a comprehensive policy prescription. Considering energy supply and end use, e.g. energy demand reduction, a balanced generation mix, storage technologies, energy efficiency and the requirements of the low carbon transition in transport and heat use.

3) A localised approach to energy provision – driving the aggregation of supply and demand at local level, especially in Scotland‟s cities. Bringing the supply of low carbon energy closer to people. Driving new models of provision that permit greater community stakes and innovation in the energy system.”

9.8 Discussions with both RSPB and FoE provided amplification of the issues relating to UCG. In partnership, RSPB, FoE and WWF produced a number of reports on energy policy. The RSPB‟s 2050 energy vision – meeting the UK‟s climate targets in harmony with nature, sets the scene. (see Annex 2 for links provided by FoE and RSPB).

9.9 „There is growing acceptance that we need an energy system that delivers affordable energy, ensures security of supply and reduces emissions – the so-called “energy trilemma”. In other words, environmental sustainability, energy security and affordability.‟ (Roddis et al, 2016)

9.10 There are also strong connections in this work with the evidenced plea for honesty, openness and alignment of rhetoric, tool and actions set out by Parkhill et al (2013) in the extensive UK Energy Research Council research package. This relates to social needs as well as to issues of supply and demand. It urges public understanding of sources of energy, not least as, which MacKay also stresses, there is seemingly so little understanding generally of how we currently light and heat our homes and drive our private, industry and business lives.

9.11 To lead and be led, we need a fuller understanding of the energy mix and the criteria which need to be met, especially when economics is so quickly overlaid over current assumed demand, the supply realities and the politics and infrastructure of the policy framework. Grid charges, gas and electricity supply networks and costs, pipeline infrastructure and the ways we heat our homes, cook our food, travel and work, all connect. Several aspects of these are not under the policy and financial control of the Scottish Government. Nonetheless, gas is now and needs to be for some time a key part of our lives in Scotland and across the UK. It is not yet in short supply globally. It is largely simply a matter of price and impact. Renewable heat and then renewable cooking and travel are „works in progress‟ and, in the climate context, these clearly need to progress quickly.

9.12 The volumes, costs and quality of the gas we use matter in relation to how it can and will be used. Coal is a high carbon fuel by definition. Gas from coal has lesser but potentially still large negative impacts. But decisions made now to use a source or develop infrastructure and contracts for that resource will have consequences for the infrastructure, markets, demand, culture and impacts of the future. „Lock in‟ is a risk. Equally a commitment to the hydrogen economy and/or full scale CCS would change markedly the parameters of the debate and the nature of what we should actively support.

9.13 SEPA has set out its policy stance and regulatory powers and interests on energy matters in SEPA (2010). This highlights, among other aspects, the potential role that regulation plays in GHG abatement and the potential value to carbon dioxide mitigation of CCS. It urges and offers,

"considering the potential environmental impacts of energy decisions, and it is within its remit to reduce these impacts. Raising awareness of environmental problems and solutions is the first step to promoting respect for the environment. SEPA has an important role to play in educating and encouraging behavioural changes in Scotland‟s response to climate change."

9.14 The Royal Society of Edinburgh (RSE) also set out a specific set of options for Scotland‟s Gas Future (RSE, 2015). They observed that,

"Scotland is heavily reliant on gas in both the residential and commercial sectors for heating. Natural gas also plays a significant role in electricity generation. Even in the event of an unprecedented decrease in UK gas consumption, a significant quantity would still be required for not only heat, but also as a chemical feedstock for the petrochemical industry.

"The UK is currently reliant on imports for over 50% of its gas consumption. To meet its future gas needs and increase energy security, local production could be increased either onshore or offshore. Action to reduce demand is also an option, but would need to occur in addition to one or several other options.

"Scotland is committed to meeting statutory climate change targets and any course of action to address Scotland‟s future need for gas must be consistent with these goals as well as addressing energy security, cost to the consumer and public acceptance. " RSE (2015)

9.15 BGS also acknowledges the nature of the geologic resource in its energy section, including the potential role of UCG, CBM, shale gas and less controversial, renewable energy sources such as geothermal energy.
(http://www.bgs.ac.uk/research/energy/home.html?src=topNav ;
http://www.bgs.ac.uk/research/energy/UCG.html)

9.16 Use of gas and generation of new gas, whether the methane or hydrogen components or other components of use, are perfectly possible. New UCG gas could provide inputs to current systems and help develop new ones, under certain circumstances. Expert opinion suggests use of North Sea sources and imports could continue and "deal with" the market price imperatives. Where UCG gas fits is not a given therefore and would depend on energy policy support, market pricing, supplying to chemical and/or energy markets and its longevity, quality and costs of supply. Use in the chemical sector and specific processes, requires careful consideration of reliability, continuity and quality of gas supplied as well as its life cycle use and emissions profile. But if Scotland is serious about a decarbonisation trajectory and the current and future planned targets in the climate change context, serious pause is needed before permitting and supporting the development of UCG for energy or other markets.

9.17 Summary

Key aspects of energy policy and the constraints and support offered by the current financial models are set at UK level, with issues such as grid access charges, overall supply management, renewables and other subsidies, etc. set essentially outside the Scottish context. Arguments abound that gas is a necessary intermediate fuel for our electricity and gas markets although it is not clear that UCG has a direct role here. A fuller analysis specifically to address this could be justified, and would need to look closely at likely conversion values, GHG intensity and GHG releases from use in the energy mix at a variety of realistic scales of use. At this point, in the context of earlier climate arguments as well as other issues around community views and the range of hazards, the evidence is not available that UCG energy inputs are necessary, sufficient or compelling to the Scottish energy market.

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10. Findings and Further Work

10.0 The evidence base available for this study is patchy and partial at best. Conclusions drawn from this evidence are also likely to be limited and thus some judgements are inevitable and necessary. This chapter points towards what can be concluded and recommends further issues for consideration.

10.1 Virtually all UCG sites have histories involving environmental or health and safety incidents. These incidents are not systematically or formally reported and catalogued. On the basis of limited available evidence, performance is neither particularly easy to assess nor easily seen as different from oil and gas exploration and production generally or other related industrial fields, especially in their early stages of development – e.g. losses of containment, gas releases, explosions, tank and bund failures, surface and groundwater pollution, liquid and solid waste management issues, etc. The context for these hazards and the risks resulting is different however when the areas of likely impact are in the populated zone and sensitive receptors of the environment around the Firth of Forth. The appetite for risk becomes crucial.

10.2 Some near-surface operations have had subsidence and seismicity events as well as gas and liquid release issues. Stories from shallow sites are concerning. Deeper operations, and those therefore more relevant to the Scottish context, are largely poorly documented.

10.3 Some operations and operators, otherwise seen as preparing very well for their operations, e.g. The Carbon Energy project at Bloodwood Creek (see Annex 3 and the 2014 presentation to the Queensland Government under Mallet, 2015 and Mallett and Ernst) still ended in failure, even if the terms of that failure – e.g. relatively limited environmental impacts and financial issues – appear of moderate magnitude, as far as robust and detailed information is available.

10.4 There have also been clear cases of worker and neighbour complaints and presentations of breathing difficulties and both eye and skin irritations suggesting exposure to poorly managed hazards. No rigorous HIA exists however in any active UCG location and no longitudinal data were found.

10.5 Commercial information is limited and suggests challenges faced by operators. Some companies, after trials and interrupted or terminated demonstrations, or even simply after seeking initial licence blocks and then observing deteriorating market conditions, have closed operations in these domains. Some have gone into liquidation, including, recently, Five Quarter in Scotland (March 2016) and Linc Energy in Australia (July 2016). In the absence of more comprehensive or robust audited information, there is simply anecdotal evidence of significant commercial challenges at some sites, even where some underpinnings from governments or major commercial companies was present.

10.6 The volatility of oil (and gas) price is commonly cited as a determining or constraining issue alongside the fundamental role of government support, both insufficient direct as well as necessary infrastructural investment, regulatory hurdles in particular excessive or overly-precautionary regulation requiring data and guarantees viewed as too much, unreasonable, too soon, etc. Generally a variety of pressures and challenges causing long times to full scale, profitable operation, inhibiting operational and commercial progress.

10.7 A number of sites have seen state or regulatory interventions, prosecutions for failures and state investigations/enquiries into operations and incidents. Largely as a result of incidents and often combined with local or general public pressure, UCG bans have been imposed in France, Germany, Queensland, New York State and HF bans might be assumed to have a collateral impact on UCG. Moratoria exist in Wales and Scotland as well as in Victoria pro tem. Elsewhere, the market alone, aided in cases by public opposition, has determined cessation or suspension or mothballing of activity.

10.8 At the beginning of this report, I referred at length to the Smith Shale Taskforce Report (2016 - https://www.taskforceonshalegas.uk/shale-gas-issues). Its recommendations seem arguably largely appropriate to their as well as this remit. I disagree, specifically in the context of UCG, only essentially with their conclusion, especially in the light of the rest of the research involved in this case.

10.9 Given the uncertainties involved it is extremely difficult to see how a positive recommendation about UCG could be made: the lack of robust data, the lack of any comparable operational site or demonstration, the need for fully transparent piloting of not only the technology but planning and licensing processes and the achievement of zero-carbon or wholly offset GHG emissions, the monitoring and safeguarding (liability management etc.) for the long term required, reasonably, to provide public reassurance and effective technical demonstration in the context of contemporary Scotland, to say nothing of the public engagement required.

10.10 Other lessons from Australian experience

Discussions with a number of Australian regulators, lawyers, activists and commentators have produced some very useful insights. A number did not wish to be quoted, including government senior staff, in some cases given ongoing legal processes and in others due to political sensitivities, partly fuelled in turn by the economic and political focus still on the resources and high carbon economy there.

10.11 Work now completed in New South Wales (NSW) brought particular insights. Professor Mary O"Kane, Chief Scientist and Engineer for NSW undertook an independent review of coal seam gas activities in NSW. I accept again that CSG is a different technology but the review"s scope and findings are once more instructive. The Review was commissioned in February 2013, “in a climate of community unease”. An initial report was provided in July that year and the final report published in September 2014.

10.12 “The Review drew on information from a large number of experts from around the world in a range of fields. It also consulted extensively with community groups, industry and government agencies.

“Having considered all the information from these sources and noting the rapid evolution of technological developments applicable to CSG from a wide range of disciplines, the Review concluded that the technical challenges and risks posed by the CSG industry can in general be managed through:

- careful designation of areas appropriate in geological and land-use terms for CSG extraction
- high standards of engineering and professionalism in CSG companies
- creation of a State Whole-of-Environment Data Repository so that data from CSG industry operations can be interrogated as needed and in the context of the wider environment
- comprehensive monitoring of CSG operations with ongoing automatic scrutiny of the resulting data
- a well-trained and certified workforce, and
- application of new technological developments as they become available.

“All of this needs to take place within a clear, revised, legislative framework which is supported by an effective and transparent reporting and compliance regime and by drawing on appropriate expert advice.

“Of course, as the technologies involved are applied in new regions where the detailed hydrogeology is not yet fully characterised, there could be unexpected events, learnings, or even accidents.

“This is common for new applications in the extractive industries and underlines the need for Government and industry to approach these issues with eyes wide open, a full appreciation of the risks, complete transparency, rigorous compliance, and a commitment to addressing any problems promptly with rapid emergency response and effective remediation.

“It also highlights the need to record and capitalise on the data and knowledge gained from CSG extraction activities in new regions and to take advantage of new technology developments which, if harnessed appropriately, can make CSG production increasingly safer and more efficient over time.” NSW (2014)

10.13 The full final report from the Independent Review of CSG Activities in New South Wales and component links are referenced below. In considering this work, it is extensive and balanced and focused in its recommendations. It highlights issues of data availability, industry performance and crucially, trust; trust between operator, regulator and community in various dimensions.

10.14 It is fundamentally important too to note critical differences in context between NSW and Scotland – just as it is with the Queensland evidence directly relating to UCG. The CSG industry is more fully developed and experienced at operational scale; described as “mature”. Even then accidents have happened. The receiving environment is different and arguably the sensitivities and impacts are different, as far as one can tell. The cultural environment and acceptance of the communities involved is different. There is at least some competition in the market place, now just two companies but formerly several more, not all with excellent reputations for their performance. There has been very significant reform in the last three years to the regulatory framework, the notion of a lead regulator, the NSW Environment Protection Authority (EPA), the requirements imposed and the resources, in both quantum and quality made available to the regulators. Other facets of what Prof.

O"Kane identifies as necessary, stand out in the Scottish context. Most dimensions seem possible to achieve but are not evident now.

10.15 Queensland evidence, specifically connected to a UCG demonstration programme is even more compelling. Depth and population context as well as basic geological issues are different but, in that resource-dominated economy, every plausible scope and support was suggested or given for the industry to do well, it seems. They did not. This is hard to ignore.

10.16 **Unanswered Questions and Data Gaps: Areas for Further Work…**

There is a series of areas for further consideration, research and challenge. This is particularly relevant if we are to balance precaution with a pro-active approach to problem solving and if tackling uncertainty is considered important in shaping future policy. Both dimensions influence the development of UCG and related policy following this review.

10.17 The aspects which follow are judgements based on a view of existing exploration, licensing and management arrangements, process and pollution abatement understanding, data availability, monitoring, public engagement etc. Surfacing existing data would in any case help address some of these questions.

10.18 I would in any case highlight the following:

10.18.1 Climate
Better background GHG monitoring is required, indeed as is monitoring of air quality generally. We do not have an adequately granular, scientifically well- or systematically located monitoring network. Nor do we have an appropriately robust time series for meaningful interpretations of most key pollutants (CO_2, CH_4 etc.). Whilst point source regulated gaseous emissions are one concern, and generally better known, background and diffuse methane emissions are another matter. Methane data are particularly inadequate to allow effective judgements to be made on issues such as natural/seasonal variation from soils and agriculture generally, including the complicating and potentially worrying dimension of sewage sludge spreading and its introduction into the mix with geologic carbon/methane etc. Equally, ambient variations, degassing of peat, characterisation and clarification of routes for groundwaters, etc., or leakage from existing former mined areas or potential future leakage, all require consideration.

Therefore both ambient data and baseline studies would be needed before meaningful site and process based monitoring would be undertaken and meaningfully interpreted.

Additionally, I understand that DBEIS commissioned WS Atkins last year to look at UCG and particularly GHG gas emissions from UCG. This would allow comparison with other gas sources. This work has not yet been published. DECC indicated it suggested exploitation would not be consistent with energy policy or climate target objectives. The Atkins study could provide valuable information and could inform policy on support for and the place of UCG both in its gas make-up in respect to energy use and chemicals.

10.18.2 CCS

Without a functioning CCS system – collection, transportation and injection/storage – accessibly close to the point of generation of syngas and with a clear understanding of its long-term effectiveness, UCG is hard to operate as a GHG balanced or carbon neutral net activity. If UCG cavities/panels were to be used for gas storage, issues of fit with the timing of UCG active processes needs to be studied and tested. Also, given the likely infrastructure and other investment costs for a CCS system, this highlights the need better to understand how the costs would be met and what sort of ownership model would apply. It appears, given experience relating to the UK and EU CCS competitions and their exemplars in Peterhead and Longannet, that £1Bn was an inadequate sum to deliver the investment needs of the cases. Practical, costed, smaller models would be desirable to explore. Norwegian experience and the potential to deliver functioning systems in China might lead to more practical and cost-effective solutions for Scotland.

10.18.3 Energy Policy/Issues

Understanding the costs of a pilot and full operation of UCG would help the consideration of the policy trigger points, were the technology to be revisited. A number of interviewees commented on the oil (and gas) price as a trigger and even noted c >$60/b for extended timescales as a possible level for viability.

Given the infrastructure issues raised above, and the costs entailed, the commitment to CCS and UCG would seem ill-advised if a decarbonising economy continues to be required for climate and energy policy reasons. Therefore, consideration of how to avoid lock-in of fossil fuel energy systems, policy and infrastructure were UCG to be progressed would be beneficial.

10.18.4 Geology

The general stratigraphy and disposition of the coal measures and their overburden is fairly well understood from historic mine plans and bores. It is evident however that in all relevant areas and relating to the CA conditional licence areas in particular, there is a need for greater bore density, for deeper ground water understanding and for consideration of the disposition of fault structures affecting the main seams prioritised for UCG use.

10.18.5 Regulation and Land Use Planning

Consideration of Best Practice worldwide would be advisable, not least to simplify, speed up, make affordable and make fair and effective any future arrangements. The mapping and construction of a coherent framework for regulation delivered by the RoadMap (SA DMITRE 2012) operated in South Australia merits some consideration. This has given industry considerable confidence and has proved a starting point for concerned communities and partner bodies and stakeholders. It is not perfect however, and the Scottish context might arguably require a more balanced approach.

A Land Use Permission

The planning model for such projects as UCG would be expensive in time and money for proponents, defenders, public bodies and public alike, especially where contested. It must be asked if a process such as the Dart CBM Inquiry is an efficient and effective model for assessment in such cases. If so, it determines a burden and a timetable, although at present it has not yet concluded. If not, there is significant scope for improvement.

B1Regulation, including Licensing, Licence condition (and ambient) monitoring/ compliance assessment all appear complex, partial and burdensome and present scope for simplification, enhanced inter-connection and better focus on the important outcomes sought. The number of parties involved seems excessive but given their different duties, roles and capabilities, a thorough mapping exercise and consideration of a simplified, prioritised and more coherent approach set in an overarching clarified mission and operational framework for delivery would be beneficial.

B2 Dealing with losses of containment, incidents, etc. Given experience worldwide, failures have occurred. Neither licences nor regulators and certainly not operators appear to have been capable of, or appropriate for, addressing these or indeed avoiding them. This would merit dedicated and separate consideration. That way, experiences, such as from the US, Canada, France, Australia and South Africa, could be learned from, licences and ex ante environmental statements and related effort (including monitoring and protective arrangements) could be robustly in place and their effectiveness reported regularly to the public and other stakeholders. Similarly both routine and emergency handling of Air Pollution, Land Contamination, Surface and Ground Waters, etc., would be factored in.

C Health issues. There is a rich literature on HIAs but no HIA of UCG operations. This need and gap should be addressed.

10.18.6 Community
Community engagement processes and arrangements are widely known and addressed in the literature. The scope for research into the status quo, public expectations of potentially good arrangements, suitable participatory models for planning and operation, setting up and operating public benefit trusts and other related arrangements would all merit consideration. In addition, processes for development and provision of objective information and establishment of neutral processes to allow dialogue and engagement tackling the existing lack of trust in operators and even some concerns about the “educational” leadership offered by companies or government would have to be explored as a starting point for any journey towards allowing UCG to progress.

10.18.7 Operations and Technology
In conjunction with geological issues, there is a need to demonstrate the actual likely displacement and changes of level post-combustion and what impact these cavity closure/collapse (subject to hydrostatic conditions, etc.,) events might have on local seismicity and whether or not these would reach the seabed or the land surface around the Forth. While monitoring on land is easier to install and that would affect the Brora, Canonbie and Midland Valley areas, sub-estuarine instrumentation would be more challenging. The application of conventional oil and gas monitoring technology might well address this but would merit expansion. Process management, control and surface monitoring and reporting arrangements for activities at depth would also likely be required.

It would be extremely useful, indeed arguably, essential, to take at least some of the site list at Annex 3 and obtain full site histories, copies of licences, performance reports and incident logs and analyses, consider monitoring data for the plants, surrounding impact areas etc. and check the EIAs against long term ambient and other site and operations characteristics. Indeed again, without this, statements that suggest the plants and operations were working satisfactorily, efficiently and cleanly simply cannot be verified, or disputed, with confidence. This is unsatisfactory, especially if confidence is to be achieved in the operator, the regulator or the minimised and acceptable impacts on the environment, community, workers and their respective health. The full loading of methane, CO_2 and other GHGs on the national account, and indeed the planet, can also not be assessed objectively or accurately.

10.18.8 Liabilities management and life cycle/monitoring/end of process arrangements.
There has been very little consideration of liabilities issues and there are long standing concerns from communities, regulators and academic observers that monitoring arrangements, oversight of sites and bonds are frequently inadequate in themselves and or inadequately policed and enforced, resulting in unmanaged risks and transfer of financial and environmental burdens to the public and the public purse. This must be addressed.

Monitoring of the end of life phase of an operation is technically feasible and, provided baseline work was conducted adequately, and oversight of long-term reassurance is also adequate, results can be interpreted and acted upon.

10.19 **Other Issues**

Emergency Preparedness and Security

10.20 Accidents and emergencies happen. Where gases and explosion risks are involved, adequate demonstration of safeguards and management practices and resourcing are required and would generally be taken into account by HSE. Other regulators, including SG itself from a civil contingencies perspective would be expected to work alongside blue-light services to provide robust arrangements. Given the still experimental and unproven nature of UCG in the Scottish context. This would require appropriate effort.

10.21 In the contemporary world and for the foreseeable future, terrorism and other criminal and disruptive activities need to be borne in mind in relation to UCG operations. It would appear advisable to ensure dialogue with the appropriate authorities under the 2004 Civil Contingencies Act. Category 1 Responders as well as engagement with HSE and SEPA to ensure flood risk as well as CoMAH requirements were taken into account. Whether or not a UCG operation and the surface syngas plant are considered critical national infrastructure, the likelihood is that CoMAH, Pipeline Safety, REPPIR and IED/IPPC regulations would apply to these elements, the connecting and distributive pipework to points of use, as well as setting some of the conditions applying to transport operations bearing connected materials – inputs, wastes and products. The involvement of pressurised and flammable gases as well as other hazardous materials would suggest careful assessment of their flows and stocks and appropriate hazard management arrangements being set in place. Were surface operations to be sited within existing CoMAH sites, arrangements would likely be most readily and easily applied.

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11.Observations and Recommendations

11.1 There is a Scottish UCG resource. Technology exits to exploit it. There is related but no analogous experience worldwide for the operational context to be contemplated for Scotland. There is public concern generally and locally. Operators, experts and public share concerns about viability and the need for further information to understand the performance and impacts of UCG better.

11.2 Costs and time to market, earnings against the world gas price market, place in that market – substitution, for example and other factors such as investor confidence and stable operating conditions, etc. are evidently industry issues.

11.3 In regulatory and policy terms, there is both a history of incidents of pollution and losses of containment, few longer term operations at scale, none under the marine environment, woefully inadequate publicly available information on licences and performance against these, including baseline and longitudinal monitoring, and a serious issue to face of achieving Scotland‟s carbon/GHG trajectory without an operational storage method and with UCG in place. Full UCG life-cycle provisions have not yet been addressed anywhere.

11.4 These issues together suggest that, while the industry could be allowed to develop, it would be wise to consider an approach to this issue based upon a precautionary presumption whereby operation of UCG might be contemplated **only** were a series of tests applied and passed. These tests would be in relation to the demonstrable and well-understood practicality and safety of the full UCG life-cycle - the end to end planning, licensing, extraction, processing, use, closure and abandonment regime including provision for long term management, reinstatement and monitoring.

11.5 Analysis suggests five interconnecting tests:

Test 1 Global/Climate Fit - Is the exploitation of UCG consistent with current and foreseen climate change imperatives and commitments made internationally and to Scottish, UK and EU climate protection measures and the minimisation of further GHG releases? This would likely require the coupling of any extraction with CCS arrangements or some other robust and validated sequestration method at least commensurate with the gas production envisaged (CO_2 and CH_4, plus other effective GHGs identified of concern at the time)(The potential for H_2 supply is an economic avenue also worthy of consideration).

Test 2 Public/Community Support – Is there sufficient public support to achieve constructive or even neutral local engagement? The dimensions of engagement would include local and general understanding and sufficient support in terms of perceived confidence, understanding and acceptance of benefits versus costs/impacts and possibly specifically approval – via elected representatives, or, via call-in methods, support of national government - of application to operate through the land use planning system. The public engagement needed to achieve local and general support would require significant effort given current attitudes.

Test 3 Operability - Does the technological capability exist safely and consistently to extract gas by UCG, convey it to a syngas processing facility and on to distribution and/or use? If UCG can be demonstrably safely operated (and life cycle completed), at the intended scale, as independently assessed other than by operators or advocates or at least adequately demonstrated to relevant regulators for licensing, principally CA, SEPA and HSE as well as to meet planning requirements, then it could be envisaged. This relates to both 2 and 4. The specific geologies, coal/gas qualities, depths etc. of the Scottish operating conditions may well need to be tested further before demonstration and operation near or at scale could be licensed. Angren, Swan and Majuba are all different geological, political, economic and cultural settings and Australian examples are much shallower as well as generally being in less populated areas than the Forth margins. Demonstrating operability is an issue as is to whom it should be demonstrated.

Test 4 Regulation - Does the regulatory regime exist to license and safely manage the operation of the UCG life-cycle so as to give confidence and reassurance to the public, workers, operators and regulators? This requires the appropriate mapping of all of the relevant elements and their practical, effective and efficient integration so as to give operator, regulator(s) and public the confidence necessary.

Test 5 Issues of the long-term - Does the liabilities management regime exist whereby there can be confidence that the life-cycle of the operations can be concluded with no unmanaged or unaffordable costs and impacts on and burdens to the community affected, to the environment or to the public purse? Bonds, insurances, monitoring, compensations and remediation practices would need demonstrably to exist at the outset, or at a relevant and controllable early point in the development process, and be sufficiently protected to again provide confidence of their long term robustness.

11.6 There are several connections between these tests. There are also several critical issues and gaps in the areas covered and, whilst potential actions to address them can be identified, it is clear that, at this time, full operation or even trialling of the technology at scale in the Scottish regulatory, planning and cultural environment, or anything of comparable standards elsewhere globally, has not been undertaken and would face serious challenges. Without addressing the issues and gaps, it is impossible realistically to assess hazards or their management and hence the risks presented and the concomitant requirements for adequate achievement of community and worker safety, the protection of the environment or public confidence generally.

11.7 Overall in framing the approach to be taken, especially the regulatory context, do the various aspects of the project, the operator, performance data and expectations, the community"s involvement and support and the governance model together suggest that a General Social Licence to operate exists? Are costs, benefits and impacts well aligned and fairly allocated?

11.8 Scotland"s world leading climate and energy commitments, the need for renewable technology development and deployment as well as decarbonisation generally, suggests pursuit of UCG, which still appears to be a developing, rather than a mature, technology, is not the right approach.

11.9 Any decision to progress towards the sort of operational environment currently applying in NSW for CSG would require not only the industry to move to that level of maturity but the very substantial transformation in available data, confidence around impacts, mitigations and liabilities arrangements, confidence in operational performance, best practice regulation in place and functioning, as well as a massive step change in both public and stakeholder acceptance and in the model of energy policy, carbon sequestration and management in place.

11.10 Progressing with UCG is also not a choice we need to make, as the coal remains available for future use as and when better full-cycle technologies or better processes and market conditions exist. Also, this appears, especially without a carbon/GHG offset method, to be a potentially expensive method – when infrastructure not currently in place is considered, for example - for obtaining a relatively dirty methane supply that would directly and indirectly further contribute to Scotland"s carbon emissions. Research, development and demonstration effort on technology, regulation, monitoring and satisfactory engagement of the communities likely to be affected to secure their support and relevant benefits, etc. is also needed and currently missing.

11.11 Consideration of the possible or ideal approach to permitting the operation of UCG would then require the positive response to all of these tests and gaps, not necessarily beyond all doubt but to acceptable degrees.

11.12 At this point, it does not appear, therefore that these tests could be met.

11.13 That being the case, it would appear logical, the current moratorium being justified, to maintain it, or, as in Queensland, and now in the context of other unconventional gas activities in Victoria in August 2016, to progress quickly towards a ban for the foreseeable future. As circumstances suggest, either arrangement could be revisited in due course were there to be a significant change in circumstances.

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Independent Review of Underground Coal Gasification – Report

Campbell Gemmell

Annex 1

A report to…The Scottish Government, Edinburgh 2016

Annex 1

The Brief for this Review and Report

The broad context of the study was addressed by Scottish Government in announcements on 28 January 2015 and specifically on 8 October 2015 http://www.gov.scot/Topics/Business-Industry/Energy/onshoreoilandgas Correspondence from the Scottish Government, dated 20 January 2016 set out the background to this review and the basic terms of reference.

"Background

The Scottish Government announced a **moratorium** on Underground Coal Gasification (UCG) on 8 October 2015. The moratorium ensures no development takes place while the Scottish Government listens to the views of communities and stakeholders, and collates evidence on the industry and its potential impact.

Ministers also announced that an independent advisor would lead a period of evidence-gathering and engagement to inform future work, analysis and decisions."

Purpose and objectives

The purpose of the review was to conduct an:

"independent and evidenced examination of the issues and evidence surrounding Underground Coal Gasification, drawing on published sources of information, expert input and community views to help the Scottish Government formulate future policies or actions."

The specific objectives of the review were to:

- "develop a robust, well researched summary of potential UCG reserves in Scotland and their potential to contribute to Scottish industry and as a source of energy;
- prepare a well-developed and evidenced description of potential environmental, health and regulatory issues associated with UCG; and
- advise on whether the technology exists to allow for safe extraction and/or on specific gaps and actions. "

This is also set out at http://www.gov.scot/Topics/Business-Industry/Energy/onshoreoilandgas/UCGIndependentReview

Deliverables

Additionally, specific deliverables of the review were set out:

- "Establishment of an advisory group and/or other stakeholder forum(s) to provide expert provide expert and stakeholder input on issues such as environmental issues and regulation, public health, spatial planning, climate strategy, community engagement, industry, geosciences, and energy.
- A report outlining the findings of the review.
- A non-technical summary of the findings.
- A summary of (or web access to) information supporting the review. This could include reports referenced in the review, minutes of meetings and presentations given."

This correspondence also set out specifically the scope of the **Final Report**.

"The Final Report should provide evidence on:

- The potential magnitude of UCG reserves in Scotland, their commercial potential and relevance to wider energy and industrial opportunities.
- The key challenges, including environmental and public health, drawing on relevant international experiences.
- The issues that are of most concern to communities and stakeholders.
- Whether the current regulatory framework (Exploration, Planning, Environment, Marine, and Health and Safety) is adequate and sufficiently integrated, and any key gaps.
- How the potential development of Underground Coal Gasification reserves in Scotland would sit with the Scottish Government's commitment to reduce greenhouse gases.
- Whether the technology exists to allow for safe extraction, with particular reference to relevant international experience and lessons.
- How to successfully and constructively engage with communities and environmental groups in a meaningful, constructive and objective basis on Underground Coal Gasification.

The report should clearly set out key findings and observations, including issues and gaps, and potential actions to address them."

The contract for the project was signed on February 16 2016.

Independent Review of Underground Coal Gasification – Report

Campbell Gemmell

Annex 2

A report to…The Scottish Government, Edinburgh 2016

Annex 2

2A Interviews and Materials Submitted

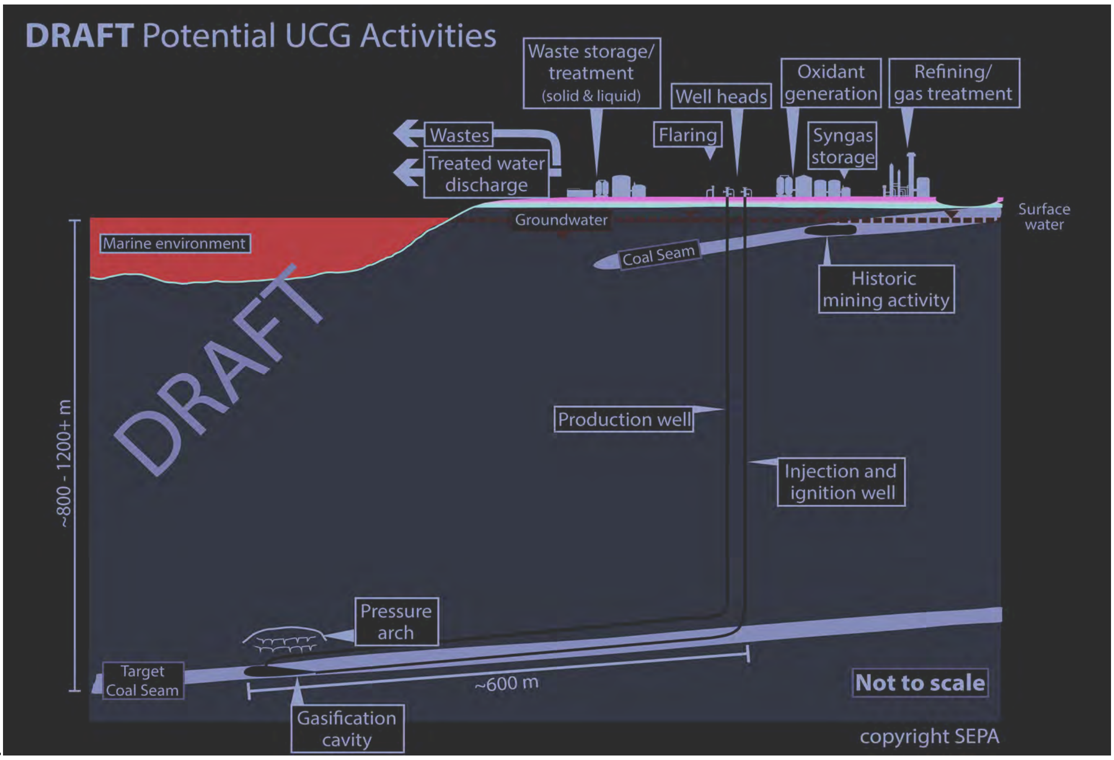
Interviews

1. Aedán Smith and Alexa Morrison, Royal Society for the Protection of Birds (RSPB)
2. Dr. Richard Dixon, Mary Church and Flick Monk, Friends of the Earth Scotland (FoE)
3. Simon Reed, Simon Cooke, Tim Marples and Nick Ethelstone, Coal Authority (CA)
4. Prof. Alex Russell, Robert Gordon"s University
5. Prof. Alex Kemp, University of Aberdeen
6. Lang Banks and Dr. Sam Gardner, WWF Scotland
7. Alison Monaghan, British Geological Survey (BGS)
8. Robert Nicol, CoSLA and John Milne, Falkirk Council/SSD/HP
9. Prof. Stuart Haszeldine, University of Edinburgh
10. Donald Campbell, Broad Alliance
11. Emily Bourne, Nick Shaw (James Clarke and Brendan Roth), Department for Energy and Climate Change (DECC, now DBEIS)
12. Dr. Colin Ramsay, Health Protection Scotland (HPS)
13. Prof. Jim Skea, Imperial College London
14. Andrew Nunn and Algy Cluff, Cluff Natural Resources
15. Tony Almond and Beverley Boyce, Health and Safety Executive (HSE)
16. Luca Demicheli, EuroGeoSurveys
17. Christian Wimmer, DG Env and Vladimir Zuberec, DG Energy, EU Commission
18. Prof. Andrew Watterson, University of Stirling
19. Ken Cronin, UK Onshore Oil and Gas
20. Prof. Zoe Shipton, University of Strathclyde
21. Mark Gifford, Chief Environmental Regulator of the NSW EPA
22. Ian Jardine, CEO of Scottish Natural Heritage (SNH)
23. Anna Donald, Marine Scotland

[Brief notes of interviews are available on request, subject to approval of the interviewees.]

Materials

SEPA



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Cause	Details	Contributing factors	Example(s)/reference(s)
Site selection (FoF target seams are 800<1300 m deep)	**This is the primary risk mitigation strategy**. - Increased target coal seam depth corresponds to decreased risk. - Must be sufficient distance from environmental receptors - Higher hydrostatic pressure allows effective gasification and reduces risk of pollutant egress. - Impermeable cap rock and absence of faulting or natural rock pathways are key. - Site must be optimised for process design (e.g. industrial scale and potential for multiple panels) and effective monitoring.	- Lack of data - Inadequate modelling - Lack of expertise (industry, operator, consultant, regulator) - Costs (commercial viability) - Poor HRA and CSM	References: - Firth of Forth UCG overview - ISP report, Queensland pilot trials (summary). ○ Recommended that guidelines/standards are developed that then serve as go/no go gates for development decision. - IEA CCC report: ○ Emphasises that due to the highly unique nature of each site and low maturity of the technology, published site selection criteria should be viewed as preliminary screening criteria. Examples: - Queensland pilot trials (summary): shallow depth (<150m) - Hoe Creek
Risk management approach	**A risk-based framework should be integrated at every level.** It should include: - A Hazard and operability study (HAZOP) - Industry best-practice safety operating procedures - Levels of Protection Analysis - Fault/event tree analysis	- Inadequate regulatory framework - Inadequate modelling - Lack of expertise (industry, operator, consultant, regulator) - Costs (commercial viability) - Poor HRA and CSM	ISP

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	- Process design that accounts for significant variability/deviations		
Monitoring		- Inaccessibility of monitoring points (e.g. in marine environments) - Inadequate regulatory framework - Lack of modelling and baseline data - Lack of expertise (operator, consultant, regulator) - Costs (commercial viability)	Examples: ISP report, Queensland pilot trials (summary): - "[Linc Energy and Crb on Energy] have yet to fully demonstrate the capability to design and install a monitoring network suitable for multi-panel operations"
Process control	**The UCG process is exposed to some unknown and uncontrollable conditions**: comprehensive and real-time process control is crucial. - Process monitoring and control should include: - Pressure/temperature - Flow rates - Mass balances - Gas quality - Critical alarms - Safety instrument systems - Pressure relief systems - Pressure control is seen as most important	- Inadequate monitoring - Inadequate regulatory framework - Lack of industry 'best practice' guidelines - Lack of expertise (operator, consultant, regulator) - Low maturity of UCG technology - Costs (commercial viability)	Examples: - ISP report, Queensland pilot trials (summary): - There was a lack of critical alarms, safety instrument systems and appropriate decisions making procedures - Several incidents occurred from lack of sufficient process control. References: Atiken for DTI
Process modelling	Needed to understand: - Chemical reactions - Heat transfer - Mass transfer - Rock deformation/stress distribution	- Inadequate data - Lack of expertise (operator, consultant, regulator) - Low maturity of science (modelling and validation) - Cost (time and money)	References: - Cavity simulation presentation Examples: - ISP report, Queensland pilot trials (summary):

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	- Cavity growth **Crucial for informing process design and risk management**. Must be validated by empirical data.		- Found process modelling and validation to be lacking.
Design, materials and construction	- Must be informed by HRA, CSM, process modelling and risk management strategy. - Must be able to cope with significant variations in thermal and mechanical stress. - Must include physical protection systems - Well integrity	- Inadequate regulatory framework	Examples: ISP report, Queensland pilot trials (summary): - Deviations in temperature and pressure resulted in weakening of the liners or lifting of the wells that subsequently failed. - Downstream po cessing couldn't cope with process variability/deviations. - Pollution incidents occurred. - Fault of poor design, materials and construction.
Decommissioning	**Aim is to extinguish the reaction, establish thermal equilibrium and prevent future environmental harm.** - Includes important changes of states in temperature and pressure, and rates of change are important. - Potentially contaminating chemicals have a high probability of forming during cooling. - There is reasonable evidence from small-scale trials ih Se UA that a 'clean		ISP report, Queensland pilot trials (summary): - Insufficient evidence has been gathered or provided for the pilot trials regarding decommissioning. - There is no evidence of the capability to control the temperature and pressure gradients in large cavities. - Extrapolation from other small cavities is inadequate, as the

	cavity' ean b achieved,ub t there are significant potential scale-up issues. - The final integrity of the cavity and overlying cap-rock is critical for minimising risk to the environment and risks increase with increasing cavity size.		process is highly dependent on site geology and process design. - Access to cavities appears to be a very challenging design issue, limiting knowledge of the decommissioning process and its success. - While several pilot trial panels have been shut down, it is unclear if rehabilitation has taken place. - A formal process model, mass and energy balances and appropriate data support were all lacking. - **Available evidence is not sufficient to develop the best strategies.** -
Multi-panel activities	**Industry Scale-up presents a number of additional potential issues**, including: - establishment of above ground and underground buffer or active zones - a design that avoids connectivity between final cavities and active panels resulting in: - unacceptable surface subsidence; - groundwater transport of contaminant - loss of control of oxygen conditions - the need for external injection of water to maintain the hydrostatic pressure across the site;		

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- a minimum distance from a UCG facility boundary and other activities (e.g. CBM) that require different hydrostatic operating conditions;
- acceptable and agreed decommissioning procedures

Main operational causes of increased risk

This table is based on information from:

ISP report, Queensland pilot trials (summary)

Atiken for DTI

SISTech report: Environmental impacts and legislation of UCG

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SUMMARY OF POTENTIAL ENVIRONMENTAL HAZARDS ASSOCIATED WITH UNDERGROUND COAL GASIFICATION (UCG)

Introduction:

The main technical challenges with regards to UCG arise because the conditions under which the gasification reaction takes place are complex, naturally variable and difficult to monitor. This, combined with potential environmental hazards, which are summarised below, creates risk.

However, currently, there are several factors limiting a robust assessment of the risks associated with UCG:

Lack of evidence of environmental impact from similar situations

Data on the environmental impacts of UCG is limited, particularly from trials relevant to the proposed target coal seams under the Firth of Forth and fro the depths being proposed (~800-1300m).. The best available environmental data come from USA trials of the late 1970s and 1980s, but these were conducted on shallow coal seams (<200m depth). The most relevant examples are the deep (> 500 m) European trials (e.g. El Tremedal, Spain), however, environmental impact data from these are either absent or limited[11].

Lack of data on impact that commercial scale UCG will have on the environment

While major trials have taken place for more than fifty years and there are dozens of current trial projects around the world, no commercial UCG project has been demonstrated[*] and there remains significant technological and knowledge gaps[1,17].

Furthermore, a recent International Energy Agency report[17] emphasises that experience and expertise from closely related fields have limited applicability to UCG, and that the techniques and technologies proven in small-scale pilot trials do not necessarily transfer linearly to commercial-scale projects as new aspects such as the greater cavity size, multiple panels and increased length of operations likely present additional challenges.

Lack of clarity about degree of regulatory control over UCG Regulatory framework

Currently, we are considering our regulatory controls and it is likely that The Water Environment (Controlled Activities) (Scotland) Regulation and Pollution Prevention and Control (Scotland) Regulation 2012, amongst others, may apply. SEPA is working with Scottish Government and other regulators including the Coal Authority, Health and Safety Executive and planning authorities to ensure we have the appropriate controls and regulations to protect the environment and human health. However, because these controls and regulations are still being clarified, it is not possible at this stage to assess the level of protection they will provide.

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[*] The Yerostigaz UCG facility in Angren, Uzbekistan, (majority-owned by Linc Energy) has been operating for over 50 years and could be considered commercial as it consistently produces 1 million m^3 of syngas per day (according to Linc Energy). However, it uses old, full depreciated equipment, the consistency and quality of syngas produced has not been a critical factor, it probably doesn't m et the environmental standards of OECD countries, and there have been no moves to scale-up the operation[17].

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Below, the main hazards associated with UCG are outlined, with relevant examples given. In a separate table, the main operational causes of increased risk are given. Note that these tables are intended to cover the full range of risks associated with UCG and are neither site- nor technology-specific, but, where possible, the Scottish-specific context is considered

Potential hazard	Details and environmental concerns	Influencing factors	Example(s)	Relevance to Scottish context
Groundwater pollution	- Consistently identified as the primary environmental concern. - Pollutants include: - Organic compounds (e.g. Phenols, PAHs, BTEX) - Inorganic compounds (e.g. ammonia, nitrogen, cyanides) - Soluble gases (e.g. hydrogen sulphide, carbon monoxide, heavy metals) - Naturally Occurring Radioactive Material (NORM). - Changes in pH can also occur - Risk depends on the potential for pollutant migration and the presence of receptors. - Waste coal ash left in situ after decommissioning poses permanent risk of groundwater pollution. - There are uncertainties over	- Inadequate site selection - Inadequate decommissioning - Groundwater flow altered post-operation - Excess cavity/well pressure - Inadequate monitoring - Inadequate process control - Well blockage - Fire/explosion - Damage to monitoring or production boreholes/wells - New pathways created due to cavity collapse and thermal/mechanical alteration of surrounding rocks - Faults/natural pollutant pathways - Intersection of historical mines	**Hoe Creek I, II & III, USA** (late 1970s, 3 shallow depth (~50m) trials): - Significant long-term groundwater pollution due to over-pressured cavity[2,3]. **El Tremedal, Spain** (1997, ~550m deep): - Main environmental impact was to groundwater and was calculated to be similar to underground tungsten mining[9] **Former Soviet Union**[14,15,17] (various trials): - Groundwater contaminants, resulting from gasification during the late 1950's ad early 1960's, found to be widespread and persistent, even up to five years after production had ceased. - Phenols were found within an aquifer which extended over an area of 10 km^2 - There were significant gas	- Developments are likely to be at >800m depth, making examples from shallow (<500m) settings less informative. - The Coal Authority would not permit developments that have potential for intersecting historical mine-workings. - Groundwater at proposed sites is likely to be permanently unusable because it is naturally saline.

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	contaminant: - generation - persistence - transport		losses due to leakage, and it was common for between 5% and 25% of the gas formed to be lost from the underground gasifier **Experimental Mre "Barbara", Poland** (2013, a 30m deep engineered reactor): - Heavy metals, ammonia and cyanides found in effluents and groundwater near the site[13].	
Surface water pollution	- Surface waste water can originate from: - process water - gas treatment - cavity flushing water - Pollutants include (same as above?) - The quality of waste water can vary significantly and rapidly This can be as a result of 1)migration from depth into surface ecosystems as row above or 2)inadequate control or disposal of waste water	- Inadequate site selection - Natural or anthropogenic features (e.g. faults, fissures, boreholes) may create hydraulic connections to the surface - Inadequate treatment/disposal of extracted waste water - Inadequate surface infrastructure, including materials, maintenance, procedures and protection systems - Excess well pressure due to: - Inadequate monitoring - Inadequate process control - Well blockage - Fire/explosion	Risk of surface incidents due to inadequate surface infrastructure and treatment/disposal of waste should be similar to conventional surface industries **El Tremedal, Spain** (1997, ~550m deep): - 240 tonnes of coal gasified -The influx of groundwater into the cavity was much larger than expected, resulting an excess of produced water with elevated contaminant levels. This was a major technical and economic problem, although no local surface water contamination was detected[11]. **Carbon Energy, Bloodwood**	- Developments are likely to at >800m depth, making uncontrolled hydraulic connections from the cavity to the surface highly unlikely, except in the case of damaged boreholes. - Discharge of waste water is likely to be into the marine environment because of its proximity to proposed sites. There will be huge dilution potential.

			Creek, Queensland, Australia (2008 to present, ~150m deep): - An injection well blockage caused pressure to spike well above hydrostatic pressure, resulting in the emission of process water through the flare[1].	
Air emissions	- Pollution of air with: - Unburned hydrocarbons - NOx - H_2S and SO_2 - CO - Fly ash - Particulates and heavy metals - Mist formation (from cooling) - Dust deposition - Greenhouse gas (GHG) release: - CO_2 - CH_4	- Inadequate: - Monitoring - Site selection - Process modelling - Construction emissions - Emissions imbedded in materials - Flaring - Refining/combustion of syngas - Venting during start-up - Fractures or old mine workings - Fugitive (escaped) gases due to: - Leaking/damaged underground and surface infrastructure - Excess well pressure - Fire/explosion - Well blockage - Combustion of syngas	- **Linc Energy, Chinchilla plant, Queensland, Australia** (2007-2013, ~150m deep): workers suffered ill health due to "uncontrolled leaks" of syngas[4]. In 2007, a coal tar blockage caused a chamber fire, Linc Energy increased injection pressure causing well casings and overburden to crack and allow syngas to escape to the surface[5]. - Lifecycle climate impacts are estimated (from few studies and limited evidence) to be less carbon intensive than electricity generation from coal but more than from natural gas[6,7,16]. Large uncertainties remain.	- Regulation of emissions to air will depend on whether PPC 2012 applies to UCG and what other activities occur on site (e.g. gas processing or combustion for electricity generation). - CCS has been proposed for sites in Scotland, which would reduce lifecycle GHG emissions. However, CCS is still in its infancy, with only one commercial full-chain project in operation in the world today.
Underground explosion	Concerns include: - Water environment/air pollution from - Highly over-pressured cavity	- Inadequate: - Monitoring - Site selection - Process modelling - Inadequate process control	- **Experimental Mre "Barbara", Poland** (2013, a 30m deep engineered reactor): cracks developed causing gases to leak and create explosive	

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	- New pathways in rock fractures - Damaged boreholes - Damaged surface infrastructure - Subsidence - Induced seismicity	- Temperatures too high - Too much gasification agent - Too slow gas collection - Damaged wells (ignition and production) - Material defect/installation error - Induced seismicity	accumulations, igniting due to high temperatures[8]. - **El Tremedal, Spain** (1997, ~550m deep): malfunction of ignition system and failure of temperature measurement system resulted in accumulation of methane and a subsequent explosion. The injection well was damaged and the decision made to terminate the trial[7,12].	
Cavity collapse	Concern: - New pollutant/air pathways in rock fractures - Impacts to surface or groundwater hydrology - Surface subsidence - Damaged surface infrastructure - Damaged well casings Details: - Surface subsidence risk deemed to be low if mitigated through site selection, e.g. - Deeper target coal seam - High structural integrity of overburden - Subsidence expected to be ~1/3 of coal seam thickness, with 98% of height loss occurring within 7 months[16].	- Uncontrolled gasification - Poor structural integrity of overburden - Disturbance of historical coal mines - Inadequate: - Monitoring - Site selection - Process modelling	Experience may be drawn from longwall mining. **Hoe Creek III, USA**[2] (late 1970s, shallow depth (~50m) trial): cavity collapse caused serious groundwater pollution and subsidence could be seen at the surface.	- Developments are likely to at >800m depth, greatly reducing the likelihood and impact of surface subsidence - The Coal Authority has stated that licences will normally only be issued in offshore areas and onshore areas where it can be demonstrated that the surface is suitable for piloting UCG. Hence, it is unlikely that surface infrastructure will be at risk.
Seismicity	Concern:	- Stresses imposed by the cavity	No instances found in the	

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	- Pollution to the water environment and air via: - New pathways in rock fractures - Damaged boreholes - Damaged surface infrastructure - Explosion from gas accumulation via new pathways	remaining after combustion - Cavity collapse - Proximity to existing faults - Use of hydraulic or explosive fracturing to link wells - Inadequate: - Monitoring - Site selection - Process modelling	literature but this may be from lack of reporting or monitoring. It is expected that induced seismicity will be small compared to mining and dam construction, for example.	
Groundwater depletion	Concern: - Supply shortage for other water users - Impacts to ecology Details: - Due to use of water in reactor - Rate of water supply into the reactor affects the product gas composition - Impact is expected to be small but uncertainties remain.	- Size of operation - Local hydrogeological conditions	The Independent Scientific Panel report on UCG pilot trials in Australia found that in some instances there is a need for external injection of water into the cavity to maintain appropriate hydrostatic pressure. It also recommended that a minimum distance is set between UCG and other activities that require different hydrostatic operating conditions (e.g. Coal Bed Methane).	If Water Environment (Controlled Activities) Regulations (2011) apply, then groundwater depletion would be prohibited.
Uncontrollable fire	Concern: - Pollution to the water environment and air - Cavity collapse Details: Risk decreases with greater target coal seam depth.	- Requires uncontrolled air/oxygen source to gasification cavity, via: - Faults/fractures/subsidence - Damaged borehole casings - Shallow target coal depth - Inadequate: - Monitoring - Site selection	No instances found in the literature but this could be from lack of reporting and the short duration of most projects. Analogous experience may be drawn from traditional mining activities.	- Developments are likely to at >800m depth, greatly reducing the likelihood of an uncontrolled air/oxygen source to the cavity occurring. - Developments will be occurring below the water

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		- Process modelling		table, making both oxygen ingress and uncontrolled combustion unlikely.

1 Independent Scientific Panel report on Underground Coal Gasification in Queensland, Australia
2 Hill RW, Thorsness CB, Cena RJ, Aiman WR and Stephens DR, 1980. Results from the third LLL Underground Coal Gasification Experiment at Hoe Creek. Proceedings of the 6th Underground Coal Conversion Symposium, Shangri-La, OK.
3 US DoE, 1997. US Department of Energy, Environmental assessment, Hoe Creek Underground Coal Gasification Test Site Remediation, Campbell County Wyoming, October 1997, DOE/EA-1219.
4 ABC News: Linc Energy allegedly exposed miners to dangerous gases
5 ABC News: Linc Energy accused of failing to report series of dangerous leaks
6 Zeshan Hyder, 2012, Site Characterization, Sustainability Evaluation and Life Cycle Emissions Assessment of Underground Coal Gasification, PhD dissertation submitted to the Faculty of Virginia Polytechnic Institute and State University
7 Muhammad Imran, Dileep Kumar, Naresh Kumar, Abdul Qayyum, Ahmed Saeed, Muhammad Shamim Bhatti, Environmental concerns of underground coal gasification, Renewable and Sustainable Energy Reviews, Volume 31, March 2014, Pages 600-610,
8 Eugeniusz Krause, Alicja Krzemień, Adam Smoliński, Analysis and assessment of a critical event during an underground coal gasification experiment, Journal of Loss Prevention in the Process Industries, Volume 33, January 2015, Pages 173-182
9 Vidal Navarro Torres, Anthony Steven Atkins and Raghu Nath Singh, Assessment of an Environmental Sustainability Index for the Underground Coal Gasification Process by Using Numerical Analysis, 14th Coal Operators' Conference, University of Wollongong, The Australasian Institute of Mining and Metallurgy & Mine Managers Association of Australia, 2014, 309-323
10 Shu-qin, L and Jun-hua Y, 2002. Environmental Benefits of underground coal gasification. Journal of Environmental Sciences, vol. 12, no. 2, pp.284-288.
11 Atkins report for DTI – Review of Environmental Issues of Underground Coal Gasification, 2004
12 Shafirovich E, Varma A. Underground coal gasification: a brief review of current status. Industrial & Engineering Chemistry Research 2009;48(17): 7865e75.
13 Kapusta et al., 2013 - Environmental aspects of a field-scale underground coal gasification trial in a shallow coal seam at the Experimental Mine Barbara in Poland. Fuel, volume 113, pages 196–208
14 Liu Shu-qin, Li Jing-gang, Mei Mei and Dong Dong-lin, "Groundwater Pollution from Underground Coal Gasification," Journal of China University of Mining & Technology 17, 4 (2007).

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15 Klimentov P P. Influence of groundwater on the process of underground coal gasification. Izv Vyssh Ucheb Zavendenii Geologiya Ixazvedka, 1964, 4: 106–119.
16 Pembina Institute report on Underground Coal Gasification Environmental Risks and Benefits, 2010
17 International Energy Agency Clean Coal Centre report on Underground Coal Gasification

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Coal Authority Power Point Presentation (2014)

The COAL AUTHORITY

Presentation to SEPA and Scottish Government

Underground Coal Gasification

Simon Reed
Director of Operations

The COAL AUTHORITY

- Brief Overview of Process
- Some findings from Queensland ISP Review
- CA Licensing and UCG
- Questions as we go along

General Process – (diagram after Linc Energy)

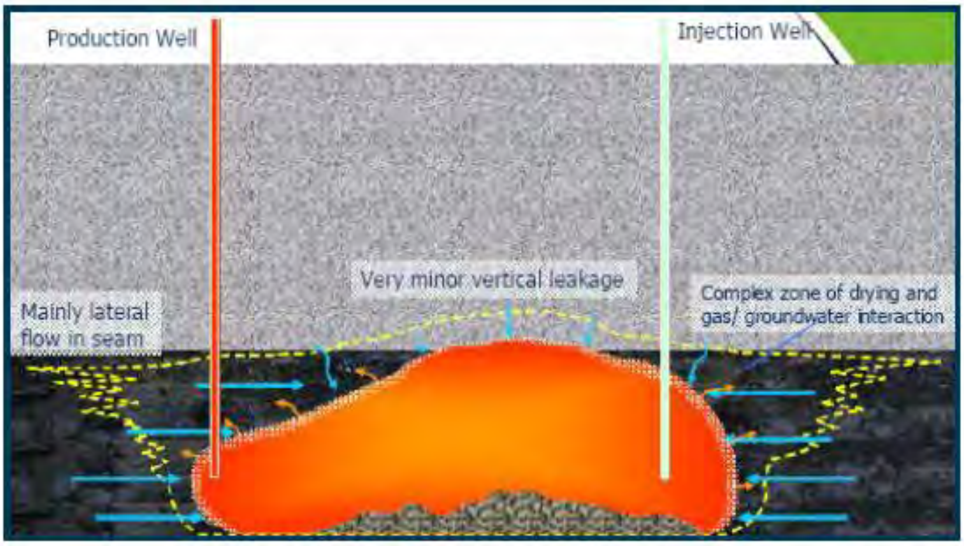
The COAL AUTHORITY

•The process generates Syngas , principally carbon dioxide, hydrogen, carbon monoxide, methane, nitrogen, steam and gaseous hydrocarbons.

•The proportion of these gases varies with the type of coal, the efficiency and control parameters of the gasification process.

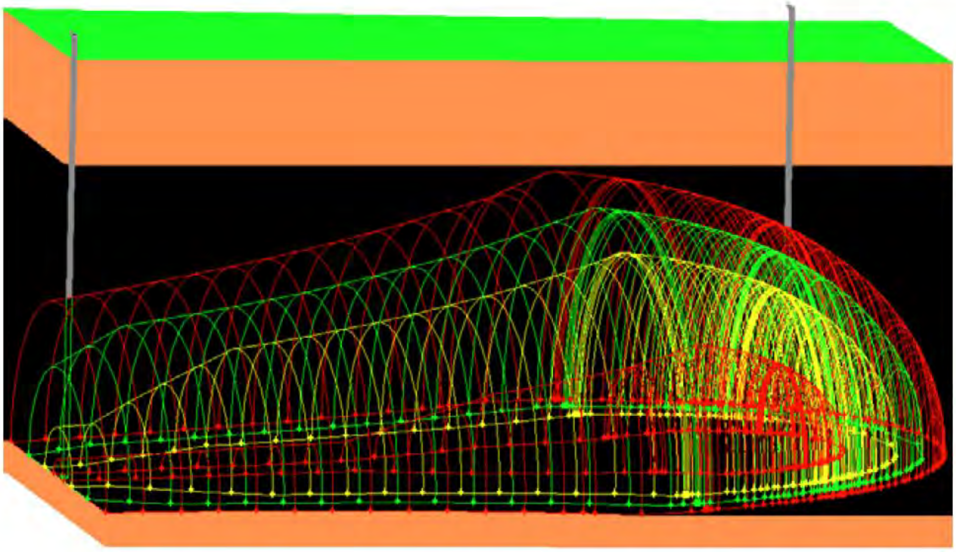
Process - Linc Energy slide

The COAL AUTHORITY



Cavity Formation - Linc Energy slide

The COAL AUTHORITY



Stages of UCG

The COAL AUTHORITY

1. Well construction and linkage:

2. Ignition: The coal seam is dried and then ignited.

Gasification is typically conducted between 900C and 1200C.

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3. Gas production:

Syngas is produced through combustion and gasification reactions.

Syngas flows from the gasification zone, through constructed or formed horizontal channels, to the gas production well.

Used for fuel for power generation, chemical feedstock, gas to liquids fuel conversion or fertiliser.

4. Decommissioning:

:

Some Pros

The COAL AUTHORITY

- Requires no manpower underground
- Enables access to coal seams that cannot be worked by conventional mining and can realise a high proportion of the energy in the coal
- Syngas is a multi-use product. Can be used for power generation or processed to extract hydrogen and manufacture other fuels (diesel, jet A1 etc), fertilisers and chemical feedstock
- Can be coupled with Carbon Capture and Storage technology

Some Cons

The COAL AUTHORITY

- “New Technology”
- Environmental Questions – potential sources of contamination
  - Loss of syngas into geological formations
  - Leaching of residual ash or tars remaining in a spent UCG cavity
  - The gasification produces chemicals that become serious contaminants if they escape the gasification cavity into the surrounding environment.
  - Issue particularly during cooling
- Will still cause coal-mining subsidence but depth and limited size of combustion chambers will mitigate the effects at the surface
- Still a fossil fuel

Site Selection – Main Technical Factors

The COAL AUTHORITY

- **Coal properties:**

  Chemical nature, structure, depth and thickness

- **Hydrogeology:**

  Groundwater supplies water for the gasification reactions
  Hydrostatic pressure serves to contain the process and drives gas towards the production well

- **Geology**:

  Good structure and low permeability of rock overlying the coal is favourable to limit subsidence and provide a seal between the coal and overlying strata.

The COAL AUTHORITY

INDEPENDENT SCIENTIFIC PANEL REPORT ON UNDERGROUND COAL GASIFICATION PILOT TRIALS

Published June 2013

Queensland Independent Scientific Panel for Underground Coal Gasification (ISP)

Examined issues relating to:

Site Selection
Commissioning
Operation
Decommissioning
Rehabilitation


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ISP Review

The COAL AUTHORITY

Pilots rather than demonstration

"Underground coal gasification could, in principle, be conducted in a manner that is acceptable socially and environmentally safe when compared to a wide range of other existing resource-using activities".

"...that for commercial UCG operations in Queensland *in practice first* decommissioning must be demonstrated and then acceptable design for commercial operations must be achieved within an integrated risk-based framework".

Specific Recommendation #4

No further panels should be ignited until the long term environmental safety provided by effective decommissioning is unambiguously demonstrated.

Selected ISP comments

The COAL AUTHORITY

a UCG site should operate under a rigorous risk-based approach which includes (selected comments):

- Coal seam to be at "sufficient" depth to ensure minimal environmental consequences.
- Coal seam sufficiently thick to sustain gasification with reasonable likelihood of economic viability
- Coal seam capped by impermeable rock.
- Target coal located so that there is "sufficient " distance to any valuable aquifer higher up the geological succession
- Sufficiently distant from rivers, lakes, springs and seeps to avoid contamination should chemical escape the cavity, sufficiently distanced from the nearest town and/or intensive surface infrastructure

Coal Authority Licensing

The COAL AUTHORITY

- A coal-mining operation requiring a licence from the Coal Authority
- The Coal Authority published its policy on UCG in 2009
  - Conditional Licences – no operations until operator has all other rights and permissions in place (land, planning, environmental, health & safety etc)
  - Offshore areas but only onshore where it can be demonstrated that the surface is suitable for piloting the technology
  - Not in existing petroleum licence areas or designated offshore windfarm areas
  - Conditional licences for 3-5 years and can only be extended if project is being developed
- UCG and CBM can legally co-exist but not practically

Underground Coal Gasification Licences

The COAL AUTHORITY

- ✐24 conditional UCG licences issued to Sep 2013
- ✐13 now expired but applications received to renew 11 of these
- ✐Extension application refused in 5 of these cases
- ✐8 applications in process, only 1 onshore (Warwickshire)
- ✐Some geological modelling but no exploratory or seismic work carried out at any site yet
- ✐CA – potential liabilities as subsidence or residual hazards in its property,

UCG, Coal Bed Methane & Shale Gas comparison

The COAL AUTHORITY

UCG	Coal Bed Methane	Shale Gas
• Synthetic Gas (Syngas)	• Methane	• Methane
• No recent commercial exploitation worldwide	• Established worldwide but not in UK	•Established in USA but not in UK
• Drills boreholes into unmined coal seams	• Drills boreholes into unmined coal seams	• Drills boreholes into shales, not coal seams
• Directional drilling	• Directional drilling	• Directional drilling
• Does not utilise fracking to produce gas	• Fracking can be used but is not always needed	• Fracking essential to release gas
• Chemical reaction	• Physical process	• Physical process
• Retains groundwater to maintain hydrostatic pressure	• Requires the pumping out of groundwater to reduce hydrostatic pressure and release methane from the coal	• Requires large amounts of water to be injected in fracking process

2B Supplementary materials provided by interviewees

I-1 RSPB

Relevant policy links:

RSPB Energy Vision Project launched on 24 May.
https://www.rspb.org.uk/Images/energy_vision_summary_report_tcm9-419580.pdf

The Energy Futures project.
http://www.rspb.org.uk/whatwedo/projects/details.aspx?id=350939

Moore V, Beresford A, & Gove B (2014). Hydraulic fracturing for shale gas in the UK: Examining the evidence for potential environmental impacts. Sandy, Bedfordshire, UK: RSPB. http://www.rspb.org.uk/Images/shale_gas_report_evidence_tcm9-365779.pdf

Durham University"s well study and ReFINE work.
https://www.dur.ac.uk/news/research/?itemno=26932
http://www.refine.org.uk/independenceethics/independentscienceboard/
http://www.sciencedirect.com/science/article/pii/S0048969715312535

I-2 Friends of the Earth Scotland (FoE)

Fuelling the Fire report.
http://www.foei.org/wp-content/uploads/2016/07/FoEI_Fuelling_the_Fire_July2016.pdf

FoEI/Stockholm Environment Institute work on Fair Shares.
https://www.foe.co.uk/sites/default/files/downloads/uks-fair-share-emissions-cuts-76425.pdf

With RSPB/WWF, FoE produced "Power of Scotland" 3 documents – Explained, Renewed, Secured - set the scene.
http://www.foe-scotland.org.uk/sites/www.foe-scotland.org.uk/files/Community_Briefing_web.pdf

http://www.foe-scotland.org.uk/sites/www.foe-scotland.org.uk/files/Power%20of%20Scotland%20full%20report.pdf

http://www.foe-scotland.org.uk/sites/www.foe-scotland.org.uk/files/possv6final.pdf

I-3 Coal Authority

The Coal Authority provided the following policy statement for licensing.

UNDERGROUND COAL GASIFICATION ("UCG")

POLICY STATEMENT FOR LICENSING BY THE COAL AUTHORITY (DECEMBER 2009)

Policy Objective

The Coal Authority ("The Authority") recognises the recent interest in UCG in Great Britain and its future potential for generating energy from its coal reserves. The Authority wishes to support its development and see UCG pilot operations established in order to assess the effectiveness and environmental impacts of this technology in Great Britain.

Statutory Duties

The Authority"s duties and obligations are set out in the Coal Industry Act 1994 under which it is given the power to grant licences for the carrying on of coal-mining operations including UCG.

This policy relates to applications for new UCG licences and variations to existing UCG licences but at this stage of development of UCG in Great Britain it is anticipated that applications will be for conditional licences.

Licence Areas

The Authority will normally only consider UCG conditional licence applications for:-

- Offshore areas. Offshore licence areas can also include an onshore access strip to facilitate the sinking of exploration boreholes during the conditional licence phase and for sinking directional access boreholes into the offshore UCG area during the operational phase. *(see note 2)*
- Onshore areas, but only where it can be demonstrated that the surface is suitable for piloting this technology. *(see note 3)*
- Areas where there are :-
    - no other Coal Authority Mining Licences & Agreements;
    - no existing Petroleum Licences;
    - no identifiable defence installations; and
    - no existing or proposed wind farm sites or other major structures on the seabed. *(see note 4)*
- A maximum initial application area of 10,000 hectares. *(see note 5)*
- Areas where the Department of Energy & Climate Change, The Crown Estate, The Ministry of Defence or other relevant bodies do not raise objections. Consultation will be undertaken by the Authority with these relevant bodies on receipt of a conditional licence application. *(see note 6)*

Licence Conditions

Licences will be subject to advertising by the Authority in order to stimulate competition.

The initial term of the Conditional Licence will normally be restricted to a maximum of three years.

The Authority will require Conditional Licence holders to undertake further discussions with the Department of Energy & Climate Change, The Crown Estate, The Ministry of Defence and other relevant bodies during the conditional period as they formulate the detail of their operations.

The conditions will include a requirement for the applicant to undertake an agreed programme of works during the term of the Conditional Licence. Failure to complete the agreed programme of works will result in the Licence being revoked unless the Authority can be satisfied that the Licensee is committed to the pilot project.

Where the proposed UCG operation and its ancillary activities have a potential to interact with or damage third party property interests then a condition will be included requiring the Licensee to provide evidence of the existence of a Commercial Agreement between the parties outlining the manner in which any interaction or damage so caused is managed, remediated and funded. *(see notes 8 & 9)*

Further requirements for de-conditionalising a licence in whole or in part will be incorporated into the licence conditions and are set out in more detail in the Authority"s Model Underground Coal Gasification Licensing Documents.

Fees and Payments

The licence application and grant fees will be the same as for underground and surface mining licence applications as published by the Authority.

The annual fee whilst the licence is conditional will be a fixed amount, currently £500 (reviewed and published from time to time) plus an agreed payment for holding an Option for a Lease of the property interest in the coal.

Policy Review

This policy shall be reviewed from time to time to ensure licence and lease terms are appropriate for developing technology.

NOTES ON POLICY

Licence Areas

1. The assumptions that the Authority has made are :-
    1. 1.1 The development of UCG will initially require pilot projects to evaluate the process in Great Britain. Once the process is proved in these conditions then larger scale projects may be established.
    2. 1.2 At this stage of the development of UCG in Great Britain, it will be easier for operators to get all the necessary permissions and consents for offshore UCG operations than onshore, hence the emphasis on offshore.
    3. 1.3 In addition to a licence from the Authority, consent for offshore UCG will be required from the Crown Estate for withdrawal of support from the seabed.
    4. 1.4 A pilot project will require an environmental impact assessment prepared by the operator rather than a strategic environmental assessment.
    5. 1.5 The syngas produced will be used for generating electricity or conversion to other petro-chemical products and the UCG operation itself will not require consent under Section 36 of the Electricity Act 1989.
    6. 1.6 The process is outside the remit for carbon capture and storage.
    7. 1.7 DECC do not require the applicant for a UCG Licence to hold a Petroleum Licence for the area applied for but at the operational phase will issue a simplified licence akin to an underground mine‟s methane drainage licence to facilitate the lawful removal of any native methane in the strata in conjunction with the UCG operations.
2. The grant of an onshore access strip will be non-exclusive so as not to prevent conventional surface mining operations, exploration or coal methane operations in that area.
3. Onshore applications will only be accepted where the Authority considers that the applicant has a reasonable chance of bringing the project to fruition. By way of an example, an application for onshore UCG by, or with the agreement of, a surface landowner with ownership of all the surface land likely to be affected by the proposed UCG operation could be said to stand a reasonable chance of getting planning consent etc.
4. Limiting UCG licences to areas outwith existing Petroleum Licences, large or proposed seabed structures such as wind farms or Ministry of Defence installations will remove some of the potential objections to licence applications.
5. Introducing a size limit of 10,000 hectares for applications (unless there are site specific issues that dictate otherwise) limits UCG applications to areas comparable to existing or proposed underground mining operations.
6. Consulting with relevant bodies (DECC, Crown Estates and MOD etc) will minimise the risk of the Authority granting a licence for an operation that may turn out to be unworkable.
7. It should be noted that a licence can always be varied to include a previously excluded area after grant if, for example, a proposed surface installation isn‟t built or an existing one ceases to operate.
8. The Authority has taken legal advice and it is still uncertain whether the provisions of the Coal Mining Subsidence Act 1991 (“the 1991 Act”) apply to offshore installations. The Authority intends to adopt a comprehensive approach and incorporate provisions in the licence to ensure that no one suffers a loss from subsidence damage arising from the actions or failures of a UCG Operator, whether or not the 1991 Act applies.

9. The requirement of the Authority to have a Commercial Agreement in place where UCG and ancillary activities have a potential to interact with or damage third party property interests is intended to be similar to the approach adopted in the Petroleum Industry.

Licence Conditions

1. Limiting the normal initial conditional licence period to three years will enable licensees to evaluate a project without sterilising the coal for an unacceptable length of time. This period can be extended by agreement if the licensee demonstrates that the agreed work programme has been carried out and further works are proposed.
2. Agreeing a work programme mirrors the current arrangements with Petroleum Licences and ensures that coal is not acquired as an asset with no intention of progressing with the operation.

Fees & Payments

1. The Licence will attract a normal annual licensing fee whether conditional and/or unconditional, as is the case with Underground and Surface coal mining licences.
2. There will be an agreed annual payment for the Option rights whilst the Licence is conditional.
3. Once the Licence is made un-conditional and a Lease is granted then rental payments under the Lease will commence. At present it is intended that these rental payments are the equivalent of the Coal Authority"s standard Production Related Rent paid for the amount of coal gasified.
4. The method of assessing the amount of coal worked will be agreed with the Licensee prior to the Lease being granted. The options could include :-
    1. 4.1 a calculation from an agreed plan based on an accurate survey of the void(s) submitted to the Authority by the Licensee at an agreed interval; or
    2. 4.2 a calculation based on an agreed formula relating the amount of syngas generated to the amount of coal worked; the syngas measurements to be supplied to the Authority at an agreed (monthly) period.

L:\Word Documents\Model Documents\2012\Underground Coal Gasification Policy.docx

I-4 British Geological Survey (BGS)

Available report which gives a map of the offshore extent of Brora coalfield here: http://www.bgs.ac.uk/downloads/browse.cfm?sec=1&cat=195 „Jurassic of the central and northern North Sea" page 79 of the document (or page 91 of the PDF).

Groundwater chemistry reports are available here: http://www.bgs.ac.uk/research/groundwater/quality/BaselineScotland/baselineScotlandReports.html and at the bottom of the page is the link to the groundwater bodies report http://www.bgs.ac.uk/research/groundwater/waterresources/ScotlandsAquifers.html

I-5 Robert Nicol, CoSLA and John Milne, Falkirk Council/SSD/HP

The following two submissions were provided.

1
Background note to meeting with Professor Gemmell
13.30 – 15.00 Tuesday 7 June 2016
COSLA Offices, Verity House, Edinburgh

Professor Gemmell is conducting an independent review of Coal Gasification. Heads of Planning Scotland will be represented by Donald Campbell (Falkirk Council) and John Milne (Falkirk Council).

Falkirk Council has experience of planning applications relating to Unconventional Gas Extraction of Coal Gas Methane through a dewatering process. Although not directly related to Coal Gasification, it is hoped that there are sufficient similarities in the proposals to offer Professor Gemmell some insight to potential issues arising from a planning authority and legislative perspective to such applications.

Planning application background

A planning application – P/12/0521/FUL – Development for Coal Bed Methane Production, including Drilling, Well Site Establishment at 14 Locations, Inter-site Connection Services, site access tracks, a gas delivery and water treatment facility, ancillary facilities, infrastructure and associated water outfall point at Letham Moss, Falkirk for Dart Energy was lodged with Falkirk Council on 29 August 2012.

As a small proportion of the site area extended into another planning authority, Stirling Council, a similar application was submitted to that authority.

The application was considered a „Major" proposal in terms of Hierarchy of Development, was preceded by a Proposal of Application Notice and procedure and accompanied by an Environmental Statement.

On the failure of Falkirk Council and Stirling Council to issue a decision [within the statutory timescales], both applications were referred to the Directorate for Planning and Environmental Appeals and a Public Inquiry concluded. On 10 October 2014, Scottish Ministers decided that the appeals should be recalled for their own determination, given the high level of public interest in the proposals.

A case update was received from the Directorate of Planning and Environmental Appeals on 12 October 2015:-

"This is one of two conjoined appeals the other being PPA-390-2029. The papers connected with both appeals can be found under this case reference. An announcement was made in the Scottish Parliament on 28 January 2015 by Mr Fergus Ewing, Minister for Business, Energy and Tourism, that there is to be a moratorium on granting consents for unconventional oil and gas developments in Scotland while further research and a public consultation is carried out. Having regard to the announcement and to the fact that it is likely that further procedure will be required in these appeals in order to consider the outcome of the assessment and review and any other relevant matters that may arise before the moratorium comes to an end, the reporters have suspended work on their report to Ministers and the appeals have been sisted to await the outcome of that process".

Application impact on Falkirk Council

Without prejudice to any decision on the applications, the submission of the proposals had significant impact on resources and procedures within the planning authority, as well as raising issue with regard to monitoring regimes and inter-relationship with other stakeholders (Scottish Environment Protection Agency).

1) The minimum level of submitted information required to accompany the application to validate the proposals was criticised.

2) On receipt of the planning application, the application was advertised as per current regulations and advice. Many contributors considered current Neighbour Notification procedures insufficient. Similarly, criticism was received that the Proposal of Application procedures were deficient for the purpose intended.

3) As the interest in the application grew, so did the number of interested parties and contributors. Over 2,400 representations were received. This had both a cost implication and a resource implication:-

a) Each written representation had to be acknowledged in writing.
b) I.T. protocols had to be established to ensure acknowledgement of electronically submitted information.
c) Staff resources to conduct information exchanges with contributors.
d) Staff attendance at Community Council and Interest Group meetings.
e) The potential of a pre-decision „hearing‟ event before recommendation was made to elected members.

4) The technical issues raised through contribution to the application could not be addressed by suitably qualified internal staff. A procurement process was undertaken to employ qualified consultants. This incurred time delay in the processing of information, criticism of „bias‟ from members of the public and considerable expense to the planning authority.

5) The resultant technical analysis produced an increased number of documents, all having to be placed in the public domain and formal consultation procedures refreshed. Criticism was made that the document increase was substantial when referring back to the original submission list – that seen fit for validation. Accusations were made of „moving the goalposts‟ and „drip feeding information‟.

6) Some technical data submitted by the applicant was subject to confidentiality limitations or could not be verified by third parties due to copyright or licensing restrictions.

7) The magnitude of interests generated by the proposal, exchanges of correspondence and response to information requests (including Freedom of Information Requests) dictated that a number of staff were allocated to the application – all to the detriment of other work commitments during that period.

8) Clarity was sought as to what – and what could not – be placed in the public domain was raised. Indexing and redacting of documents had a significant cost in terms of time

and expense.

9) The „Precautionary Approach" advocated through Environmental Impact Regulations required technical assessment of the proposals and questioning whether it was the role of the planning authority to review matters which it seemed more appropriate to be within the remit of another stakeholder. As an example, the Regulatory duty of the Scottish Environment Protection Agency (SEPA) was examined and some criticism made that the planning authority was deferring monitoring and enforcement both above and below ground to that authority, rather than tackling these matters through application of the Environmental Impact Regulations.

10) In both the case of Falkirk Council and Stirling Council, external legal representation at Public Inquiry was sought. This presented an additional cost implication dictated by limited internal resources.

11) Questions were raised as to what issues are „material" when considering such planning applications, not least the issue of Public Health.

These anecdotal examples are not intended to be an exhaustive examination of the general approach to all Unconventional Gas planning applications but should reflect the potential impact of such proposals on a planning authority in an environment where transparency, communication and community engagement are promoted. Not least, it should also provide an example of where the planning application fee associated with proposals is far outweighed by the expenditure required by the planning authority to secure robust analysis and determination.

2

FEEDBACK ON THE PROCESSING OF A MAJOR APPLICATION - DART ENERGY - P/12/0521/FUL (Development For Coal Bed Methane Production, Including Drilling, Well Site Establishment at 14 Locations, Inter-Site Connection Services, Site Access Tracks, a Gas Delivery and Water Treatment Facility, Ancillary Facilities, Infrastructure and Associated Water Outfall Point AT Letham Moss, Falkirk, FK2 8RT)

FALKIRK COUNCIL APPEAL REF : AP/13/006/PPA

RECAP/LESSONS LEARNED

[Prologue by Head of Planning & Transportation, Falkirk Council
As background to this document, two points should be noted. It is a draft which will not be completed until the planning application has been determined by Ministers and all the Council‟s relevant officers and consultants have been able to contribute to it. More lessons may emerge by then.

References to "lessons learned" variously include confirmation of the approach actually taken by the Council as well as issues which might be handled differently in future.]

1. General Comments

1.1 Very unusual case/circumstances, so lessons learned may have limited (less) relevance to future cases.

1.2 Committee decision [that it would have refused planning permission because of the lack of some relevant information] was defended, and threatened claim for expenses was not submitted. Members of public who attended thanked Dr Salmon for his evidence, and Neil Collar for his Closing Submission.

1.3 AMEC Technical Notes provided a sound audit trail.

1.4 Importance of tailoring approach to personalities involved - e.g. DPEA warning to Messrs X & Y.

2. Pre-Application Stage

Issue

- Participation by Falkirk Council in Proposal of Application Notice Procedure

Concern

- No concern. The planning case officer participated in detailed pre-application discussion with the applicant. Attended a scheduled public exhibition and participated in a joint site visit with the applicant.

- As the proposal also involved Stirling Council, an early liaison meeting was conducted with representatives from the neighbouring planning authority.

Lessons Learned

- Early dialogue with the applicant essential.

- Close liaison with representatives of neighbouring planning authority established.

- Could have considered the use of a processing agreement?

3. Application Stage

Issue

- Document management.

Concern

- The large volume of individual representations received required careful recording.

- As is normal practice, hard copy representations were destroyed after scanning to file.

- Summary totals on-screen did not match up.

- Large volume of "community mandate" electronic documents required a new IT protocol to be established.

- Public access to documents.

- IT capacity on individual PCs.

Lessons Learned

- It is acknowledged that individuals may make multiple representations - online and in writing - which make the same comment. These submissions contribute to the total representations received and may give a slightly skewed impression.

- If possible, thought should be given to retaining hard copies of representations. In this instance, 2,486 letters of representation had to be printed out for submission to the DPEA. These documents had to be accompanied by an index of individuals and addresses. It may not, however, be practical to predict which future application this would apply to.

- In addition to individual representations, a "community mandate" document was available to submit. Electronic and paper copies were submitted. A separate classification was added to the Uniform system for "Community Mandate", and allowed these documents to be distinguished from representations received.

- With the helpful assistance of a third party - a community mandate co-ordinator - the co-ordinator collected a large volume of mandates, collated them and - in co-ordination with Falkirk Council - directed these to a separate "dropbox" which was uniquely and solely for that purpose. This was extremely beneficial in terms of document handling by the planning case officer.

- Public access to documents was a high priority for 3rd parties. Taking into account the high public profile of the application, it was considered prudent to allow public access to more than the documents submitted by the applicant. External consultation responses were published, as were all 3rd party representations. The publication of 3rd party representations required writing to contributors, advising them of the publication of the documents and seeking their acceptance or otherwise in relation to this change in procedure. Acknowledgment letters issued on receipt of representation on all planning applications could be adapted to accommodate this procedure if considered appropriate in other applications.

- Public representation of 3rd party representations dictated that each representation was read and suitably redacted prior to publication.

- The volume of large documents received by the case officer substantially reduced the operating speed of the receiving PC. In addition, Falkirk Council's threshold for document size also created difficulties in communication. Common practice in placing large documents in "dropboxes" for access is not a practice shared or adopted by Falkirk Council. The receipt of multiple large documents remains problematic.

- Physical storage space to store hard copy documents remains an issue.

Issue

- Allocation of case to officer.

Concern

- The major application generated daily workloads of a significant volume, which required prompt response and co-ordination. The demands of the application pushed other workloads to a lesser priority.

Lessons Learned

- Planning Co-ordinator recognised [the case officer"s] workload pressure and limited allocation of additional workload accordingly. The reduced workload allocation allowed time to focus on this planning application.

- The introduction of several other colleagues within "Team Dart" with regular meetings allowed issues to be fully discussed, views shared, feedback given and positions agreed in relation to progressing matters.

- The information sharing within "Team Dart" allowed access to other officers in the absence of the case officer. This facilitated early response to 3rd parties.

Issue

- Keeping elected members and the public informed.

Concern

- Misinformation to elected members.

- Political polarisation on any decision.

- Confrontation with contributors to the application.

Lessons Learned

- Need to be and be seen to be neutral on the application important and ensuring that this was reinforced at meetings, in conversation and in correspondence.

- Regular published updates on Falkirk Council website is productive.

- Case officer cannot be confrontational to 3rd parties and should emphasise transparency in the processing of the planning application.

- Advise/seek view of elected members in relation to the need for a public hearing, prior to any recommendation on the application.

- Allowing flexibility in "material considerations" and, if necessary, introduce new consultees (e.g. consulting Public Health Division on concerns over health issues).

Issue

- Review of EIA.

Concern

- Council did not issue request for further information per Regulation 23.

Lessons Learned

- While request for further information was made, the approach was not formally made quoting Regulation 23. Regulation 23 should be quoted on future approaches on EIA information requests.

Issue

- Complex technical nature of application.

Concern

- Lack of "in-house" experts to address technical concerns.

- Clarification of roles and responsibilities (i.e. Environmental Health and methane monitoring).

Lessons Learned

- Early commissioning of external consultants essential.

- Clarification of roles and responsibilities enabled by facilitating meeting of relevant parties (i.e. Environmental Health and SEPA).

Issue

- Adhering to timeline for determination.

Concern

- Managing expectations of applicant, objectors and elected members.

Lessons Learned

- Essential that thorough analysis of technical concerns is undertaken. Where there is doubt, revisit the topic until there is satisfactory resolve.

- Objectors and applicant may have access to technical "experts", therefore it is critical that Falkirk Council was - and seen to be - reasonable and thorough in technical evaluation.

- Scrutiny takes time. Applicant formally approached through extension of time letters. Update papers provided at Planning Committee prior to formal recommendation.

- Communication with Stirling Council maintained and "common views" identified.

4. Appeal Stage

Issue

- Instruction from elected members as to Falkirk Council's position in the appeal process.

- Legal advice.

- Submission of documents to DPEA.

- Potential costs.

Concern

- Gaining consensus of opinion on the proposal, where no recommendation had yet been made.

- Likely to be complex and time consuming appeal process.

- Impact on staff time.

- Impact on budget.

Lessons Learned

- Case officer has to be afforded the time to concentrate on the application, additional workload reviewed and monitored.

- Budget has to be available to allow external consultees to be involved in the appeal process, including external legal advice.

- Early meeting with DPEA to agree submission details (i.e. electronic/paper submissions and formats) proved useful.

- Administration demands to generate paper copies of over 2,000 letters of objection.

- Conforming to deadlines set by DPEA essential.

- Report to Planning Committee timeous and non-committed to single course of action - explain the options and let Committee decide.

Issue

- Consequences of Pre-Examination Meeting.

Concern

- Allocation of appropriate personnel to individual topics set by DPEA.
- Establishing communication protocols with DPEA, applicant and other parties.
- Adhering to timescales set by DPEA.
- Document exchange protocols.

Lessons Learned

- Inform internal consultees about their likely participation in the process. Not all consultees are aware of the appeal process.
- Establish which consultees need to prepare hearing statement or precognitions and set the timescale. Many consultees not aware of this process and needed previous examples provided.
- Close working with legal team advised and review of statements/precognitions undertaken. Ensure there is sufficient time for revision.
- The DPEA allowed further documents to be submitted between parties. This required co-ordination and recording by the case officer, ensuring consultees were appraised of new information and were allowed to respond appropriately.

Issue

- Instruct DPEA to participate in a Joint Statement of Common Understanding, including schedule of potential planning conditions.

Concern

- Busy exchange of e-mail traffic, including liaison with legal advisers, consultees, appellant and Stirling Council.

Lessons Learned

- Division of workload beneficial, with Development Management colleague isolating planning conditions as a separate task.
- Resolving opinions not always easy. Legal advisers, consultees and Falkirk Council all having opinions which had to be met and concluded.
- Tight deadlines led to some frantic evening working.
- Capacity issues of PC hampered e-mail exchanges.
- All parties had to be informed through an ongoing process as to changes in approach/working within draft agreement.

Issue

- Document production and receipt prior to Inquiry.

Concern

- Ensuring all documents, when received, sent on to consultants for review and potential impacts on precognitions and hearing statements identified.
- Ensuring all productions distributed and made available as required.

Lessons Learned

- Electronic document exchange a huge undertaking, requiring careful administration.
- PC capacity issues hampered exchanges.
- Having documents couriered quickly was problematic. Administration process failed.
- Reviews of hard copy submitted documents from appellant raised significant issues (documents indexed but not lodged), resulting in extensive e-mail exchange with DPEA and appellant.
- Physical storage and handling of a large volume of documents required to be addressed.
- Falkirk Council productions lodged and circulated timeously. No reminders from DPEA.

Issue

- The Public Local Inquiry and Hearing Sessions.

Concern

- Was Falkirk Council input considered (including by others) as being sufficient and robust?
- Hard copy document access during appeal sessions.
- Appropriate management of Falkirk Council participants.

Lessons Learned

- The DPEA session list approved at the Pre-Examination Meeting determined the appropriate people at the appropriate session. This was largely achieved.
- Development Management representatives attended every relevant appeal session, even when not actively taking part.
- The physical transfer of 17boxes of documents was problematic, especially when venues were changed.
- No IT support during appeal sessions (iPads, laptops, etc.).

- Instructions by the DPEA during the appeal sessions dictated swift response (e.g. site history session with appellant/objectors).

- Late night working by consultees and legal team dictated early morning workload for case officer, i.e. printing out documents, retrieving specific information, etc., prior to start of appeal sessions.

- Availability of case officer had to be assured.

Summary - Lessons Learned

- Team approach beneficial on major applications.
- Recognition given to case officer in terms of other workload.
- Good communication between stakeholders essential.
- Recording of information exchanges laborious but essential.
- IT capacity issues can hamper flow of information.
- Public domain issues require to be resolved early, i.e. advising 3rd party representatives that comments may be available to review.
- Document management requires careful attention.
- Stakeholders require to be periodically informed of progress, i.e. bulletins on web page, Planning Committee update papers, etc.
- Early decision making on commissioning of consultants is beneficial, while commissioning process could be streamlined.

Action Points

- IT capacity issue needs explored, along with potential dropbox option for very large documents.
- Uniform system needs reviewed to allow public access to specific documents.
- Standard acknowledgement letter/e-mail to contributors to an application should make them aware that their representation will be made publicly available.
- Commissioning of external consultant process requires clarification.
- IT handling of large volumes of representations needs reviewed.

I-6 Broad Alliance
The Broad Alliance provided the following submission.

Why
Underground Coal Gasification
Should Be Banned

Submission of Evidence Against the Planned Underground Coal Gasification Trial in Kincardine

and

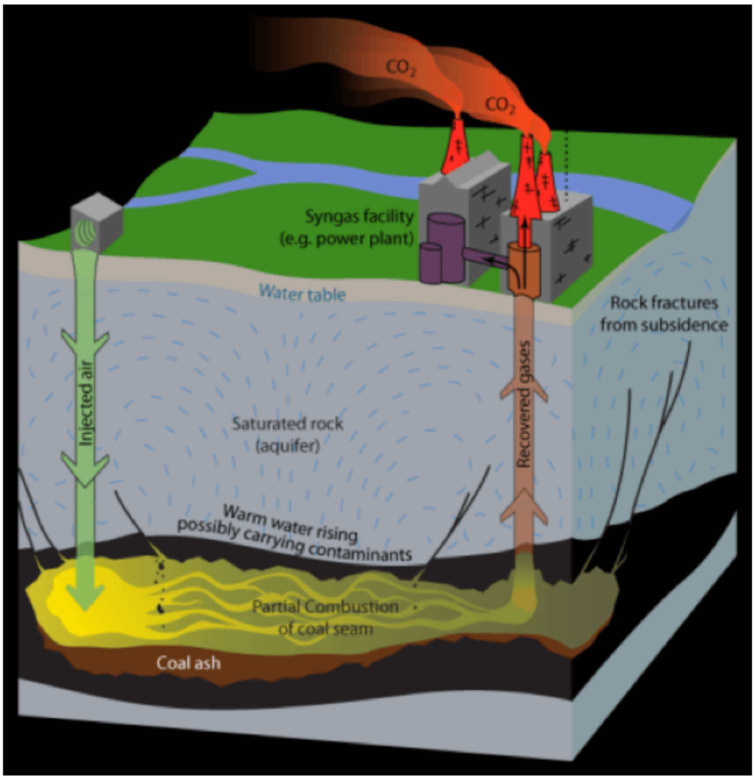
Other Conditional UCG Licenced Operations Across Scotland

08 July 2016

Contents

Introduction

Underground coal gasification is a process to burn coal underground, where it lies, to produce synthetic gas (syngas), instead of burning coal safely in power stations, i.e. creating underground gasworks (Pearce 2014)[1].



Slide 28 of a presentation on the "Status of Underground Coal Gasification (UCG) as a Commercial Technology" **(**Dryburgh,2005**)**[2] states

> "Despite 50 years of trials no commercial UCG project has been demonstrated. There has been a great deal of recent progress with pilot projects showing considerable promise and the current pilots could result in commercial operations within five to seven years, providing greatly increased confidence in the technology."

It had been hoped new horizontal drilling techniques could prove to be the breakthrough that would prove UCG could finally be undertaken safely.

The Queensland government decided no industrial scale UCG operations could go ahead until three trials, by private companies, to be monitored by the Queensland government, were undertaken first, to assess if UCG could finally be undertaken safely using the latest horizontal drilling techniques, after other recent trials around the world reported issues with groundwater contamination with cancer causing chemicals and an uncontrolled explosion that resulted in the EU trial being abandoned.

The Westminster Government has issued conditional Underground Coal Gasification (UCG) licenses across Scotland, England and Wales, to brand new companies, set up to apply for the conditional UCG licenses, companies with absolutely no UCG experience, with Cluff Natural Resources Kincardine UCG license chosen to be the one used to conduct the pilot of UCG in the UK using new horizontal drilling technology.

Julie Lauder, CEO of the Underground Coal Gasification Association (UCGA), based in London (which has now gone into administration), claimed the Linc Energy UCG trial in Chinchilla, Queensland has proved to be the "eureka moment" for UCG. (Pearce 2014)[1]

This statement proved to be premature as in April 2016 the Queensland Government"s Natural resources minister Dr Anthony Lynham declared all commercial UCG was completely banned immediately **(**Associated Press 2016**)** [3], with laws to follow, all remaining trial sites would be decommissioned, with the state environment minister, Steven Miles, saying

> "What we have in Hopeland, near Chinchilla, is the biggest pollution event probably in Queensland"s history," Miles said. "Certainly the biggest pollution investigation and prosecution in Queensland"s history."

This submission is intended to present the evidence, which we believe proves conclusively, based on the results of latest trials around the world, using world leading horizontal drilling techniques and other evidence widely available, including two reports commissioned by Cluff Natural Resources, that underground coal gasification (UCG) still cannot be undertaken safely, which is why, like the Queensland Government, the Scottish Government should enforce a complete ban on underground coal gasification immediately, with laws to follow too, the Kincardine UCG trial proposed by Cluff Natural Resources stopped from going ahead and all UCG licenses revoked.

The Broad Alliance : Who We Are

We are an alliance of groups from Scottish communities directly or indirectly at risk from the unconventional gas extraction industry, within Scotland.

Broad Alliance Community Group Members include :

Canonbie and District Residents Association	Canonbie
Clacks Against Unconventional Gas	Clackmannan
Concerned Communities of Falkirk	Falkirk
Don't Frack The Brigg	Bishopbriggs
Dunbar Anti Fracking Team	Dunbar
East Lothian Against Fracking	Pencaitlan
Halt Unconventional Gas Extraction	Cumbernauld
Highlands and Islands Against Fracking	Highland districts
Iona Community Mull and Iona Family Group	Iona
No Fracking North Berwick	North Berwick
Our Forth	Portobello
Kincardine CC	Kincardine, Fife
Coastal Regeneration Alliance	
PEDAL (Transition Grp)	Portobello
Transition Stirling	Stirling
Markinch Environmental Action Group	
A Greener Melrose	Merose
Transition Town Linlithgow	Linlithgow
South Lanarkshire Against Unconventional Gas	
Frack off Fife	Fife
Coal Industry Social Welfare Organisation	
Denny & Dunipace Against Unconventional Gas	Denny & Dunipace
Midlothian Against Fracking	Midlothian
Stirling Against Unconventional Gas Extraction	Stirling
Greens (Dumfries & Galloway)	Dumfries & Galloway
Scotland Against Fracking	Central Belt
Friends of the Earth Stirling	Stirling
Friends of the Earth Falkirk	Falkirk
Glasgow Frack Watch	Glasgow
Torrance Against Fracking	Torrance
Forth Under Fire	
Scottish Pagans Against Fracking	
Frack Off West Lothian (FOWL);	West Lothian
Shotts Say Frack Off	Shotts
Frack Free Forth Valley	Forth Valley
Milton Community Garden Group	Milton

Supporters of the Broad Alliance include:

Friends of the Earth (Scotland)
Unison Scotland
Radical Independence Campaign (National Forum)
Women"s Environmental Network Scotland
Radical Independence Campaign East Kilbride
Environmental Justice Network
Scottish Education and Action for Development
Frack off Scotland
Transition Scotland
Coal Action Scotland
BioFuels Watch
Educational Institute of Education, Further Education Lecturers Association
Scottish Hazards Campaign
Reclaim the Power Scotland
Assemblies for Democracy

The Queensland UCG Pilot Experience which has resulted in a ban on UCG in Queensland

UCG trials in Wyoming America (Burton, Friedmann, Upadhye, 1993)[4], leached into groundwater with "Elevated levels of coal tars, residual organic carbon, BTEX (benzene, toluene, ethyl benzene, xylene) found in coal seam and overlying aquifers.

As a result the Queensland Government in Australia decided no industrial scale UCG could go ahead unless three small scale trials were undertaken, by private companies Carbon Energy, Cougar Energy and Linc Energy, while being closely monitored by the government to prove UCG could finally be carried out safely.

Within a year, Carbon Energy"s small UCG trial in Bloodwood Creek contaminated water and land with cancer causing chemicals, which the company failed to report **(**Nancarrow 2011**)**[5], forcing the Queensland government to shut down the trial for seven months and also resulting in Carbon Energy being fined $62,000 (plus costs) in court for the environmental damage caused and breaching environmental protection laws **(**Powell, 2012**)**[6]**.**

Within weeks of Cougar Energy"s UCG trial in Kingaroy commencing in 2010, the trial contaminated groundwater with cancer causing chemicals, with directors failing to notify the authorities as quickly as they could have done, **(**Wall 2011**)**[7] which resulted in the trial being permanently shut down by the government, with Cougar Energy fined $75,000 in September 2013 **(**Powell, 2013**)**[8].

Cougar Energy abandoned UCG operations and announced they were changing their name to Moreton Resources declaring "its current name is strongly linked to UCG and may be disadvantageous for attracting and retaining the support of investors in the future **(**Yeo, 2013**)**[9].

Julie Lauder, the CEO of the UCG (trial) Association in London (which is now in administration) claimed Linc Energy"s Chinchilla UCG trial in Hopeland Queensland was to be the "Eureka Moment" for UCG **(**Pearce 2014**)**[1].

In June 2013 the Independent Scientific Panel Report On Underground Coal Gasification Pilot Trials (Moran, de Costa, Cuff, 2013)[10] recommended a continued the ban on commercial scale UCG in Queensland as the two remaining trials had "still not proven they could demonstrate safe decommissioning, by extinguishing the fires, shutting off reactions and preventing groundwater contamination."

In November 2013, unhappy with this decision by the independent panel of Scientists, Peter Bond, CEO of Linc Energy said they were shutting down their Chinchilla UCG trial and transferring operations to Asia, Peter Bond claiming this was "Due to the regulatory uncertainty" (Validakis, 2013)[11].

The Queensland government announced five months later, as a result of a nine month ongoing investigation, they were taking Linc Energy to court on four counts of causing serious environmental harm (Willacy, 2014)[12].

But later news reports revealed, just weeks before Peter Bond"s announcement his company"s offices were raided after search warrants (Frost, 2015)[13] were issued on the basis of tip offs from former workers regarding alleged toxic gas leaks and other serious problems at the Linc Energy plant (Solomons, Willacy, 2015)[14].

As investigations continued, by 1st March 2015, the Queensland government issued a warning deadly gases carbon monoxide, hydrogen and hydrogen sulphide had been found just below the surface in two private properties in the Hopeland area, near the Linc Energy UCG trial, with farmers told not to excavate below two meters unless they contact the government first (Willacy, 2015)[15].

Yet the next day, on the 2nd March 2015, Fife Today (Trimble, 2015)[16], in an article headlined "Cluff claims UCG plans for Forth pose „negligible risk"" the Chief Operating Officer of Cluff Natural Resources, Andrew Nunn, declared their planned UCG trial in Kindardine posed "negligible risk", making no reference to events unfolding in Australia claiming

> "The only way to further the evidence base is to proceed in a cautious manner with a small pilot operation with rigorous oversight from all the various regulators and members of the local community."

This despite the fact it is well documented all three UCG pilots in Queensland had resulted in major environmental damage, with what could be the biggest environmental disaster in Queensland"s history reported the previous day, due to the Linc Energy UCG trial – despite close government monitoring with rigorous oversight from all the various regulators and members of the local community.

Andrew Nunn went on to say, as opponents of called for it not only to be included in the moratorium but completely banned

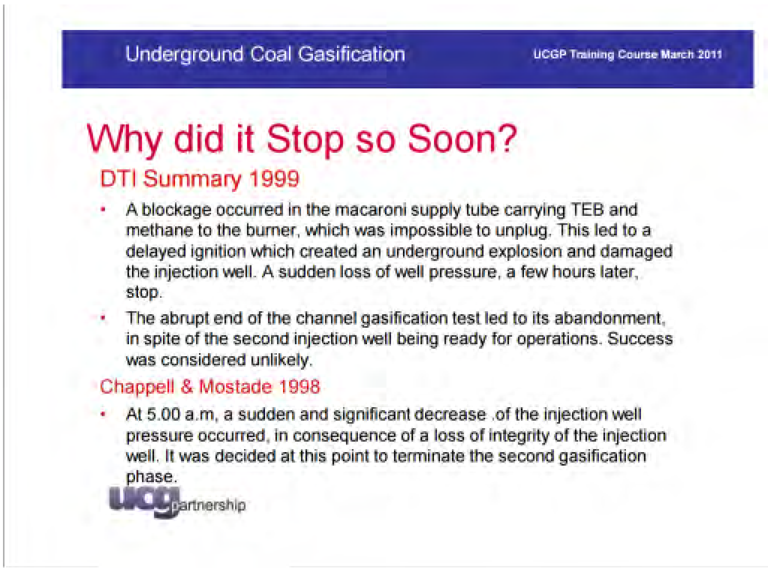
> ""This scientific study was carried out between 1999 and 2009 and culminated in a feasibility report for a UCG demonstration project in the Firth of Forth. The Scottish Government has always been committed to an evidence-based approach to energy Policy and the deliberate exclusion of UCG from the moratorium is acknowledgement the evidence base for UCG already exists.""

The UCGEngineering.com[17] website reveals, the study Andrew Nunn refers to was

> The trial was undertaken by the Spain, the UK and Belgium, and was supported by the European Commission.
>
> The Spanish trial was completed successfully (although operating hours were low) and it demonstrated the feasibility of gasification at depth, the viability of directional drilling for well construction and intersection and the benefits of a controllable injection and ignition point (CRIP- controlled retractable injection point)."

But what Andrew Nunn, the UCG Engineering website and Westminster‟s DECC website[18] also do not reveal was this UCG trial had to be completely abandoned after the pipe feeding the combustion products got blocked, resulting in an explosion, which could not be controlled, covering the surface site in contaminants and the entire UCG trial had to be abandoned, with DECC only stating

> "the trial demonstrated that UCG wells in deep seams could be successfully constructed. The encouraging results of the European trial led the DTI to reevaluate UCG as a longer-term option for clean coal exploitation in the UK, as described below."



So with no mention of the fact the part funded DTI EU trial was forcibly abandoned after it was impossible to unplug a blockage in the tube carrying the TEB and methane to the burner resulted in an explosion that could not be controlled , as revealed by the European UCG Case Study **(**Green 2011**)**[19] revealed why the UCG trail had to stop so soon.

While Andrews Nunn goes on to claim

> "The only objection to this sort of scientific approach can be that it will expose the extremists‟ anti-UCG rhetoric for what it is and leave communities wondering what all the fuss was about."

and

> “Unfortunately for those opposed to UCG, you cannot randomly pick which scientific evidence you choose to believe in. If you accept unequivocal evidence for climate change you also have to accept similarly strong evidence that a well-executed UCG project will have a negligible risk of adverse environmental outcomes.”

With Andrew Nunn failing to mention the EU trial was forcibly abandoned after an underground explosion it appears it is Andrew Nunn being picky with the scientific evidence, along with DECC and the UCG Engineering website.

On 12th March 2015 “a court ruled Linc Energy will stand trial on five counts of wilfully and unlawfully causing serious environmental harm” between 2007 and 2013 **(**Frost, 2015**)**[20].

Meanwhile in Britain, on the same day, academic expert Harry Bradbury, the boss of Five Quarter, who held UCG licenses in the Firth of Forth, at the time, claimed those protesting against the UCG proposals who had signed a petition against his company‟s UCG plans for the North East coastline where being “alarmist” and were “misinformed” (McCusker, 2015)[21], with the report going on to say

> “About its technology Mr Bradbury was unequivocal.”
>
> “Five-Quarter is not running experiments – the initial technology roll out uses technology tested over 15 years with five years of Australian Government monitored trials using expert witnesses, the results of which have been that the follow-on commercial programme has full Government approval.”

With Harry Bradbury making absolutely no mention of the disaster unfolding in Australia as a result of the Linc Energy flagship UCG trial – after Linc Energy had fled the country months earlier with the Queensland government suspecting the coal fire may still possibly be burning underground from that Linc Energy trial, the Cougar Energy trial being closed down within weeks of starting and the Carbon Energy trial also resulting in a court case- 100% of the UCG trials in Australia resulting in 100% of the companies being taken to court for causing serious environmental damage.

By 17th March 2015, further reports stated Linc Energy were facing further allegations, (Solomons, Willacy, 2015)[22]. with the ABC News report revealing staff complained to the company of nose bleeds, dizziness, nausea, vomiting, headaches, blurred vision and respiratory ailments, which the company is alleged to have failed to report , with another news report claiming it had been confirmed, the workers had been exposed to toxic gases (Hagemann, 2015)[23].

Linc Energy"s Chairman is quoted as saying in response to the allegations "We have not received direct complaints from former employees (Solomons, Willacy, 2015)[22].

Further allegations claim "unreported incidents at Chinchilla allegedly include a fire caused by a clogged pipe" and Linc Energy knew in 2013 all the gasifiers were fractured, with fractures also occurring on site, which also happened in the EU trial causing an explosion that could not be controlled which resulted in the the entire UCG trial having to be abandoned (Solomons, Willacy, 2015)[22].

The blockage in the Linc Energy trial, "which the company tried to clear by increasing the pressure so much that the rock above it cracked, allowing the gas to escape"

It was also alleged that groundwater was contaminated with benzene, at levels 60 times higher than allowed and attempts were made to hide gas leaks by covering them with crusher dust and that carbon monoxide was penetrating the surface as well as syngas from Gasifier 4, with the management of Linc energy aware of this and ordering staff to reduce the pressure during a site inspection by Government staff to conceal the leakage (Solomons, Willacy, 2015)[22].

The news report also states the Environment Department also alleges "extremely high levels of contaminants were recorded at monitoring wells on the site, with levels of contaminants so high a third party laboratory, which tested samples, rejected them on the basis they could damage laboratory equipment" **(**Solomons, Willacy, 2015**)**[22].

So both Cluff Natural Resources and Five Quarter, both holders of UCG licenses in the Firth of Forth, make statements at the same time this UCG trial disaster in Queensland was unfolding, which combined claimed those against their UCG trials are being "alarmist" and "extremists" and being picky with evidence.

Harry Bradbury also stated his plans to go into full industrial scale production in the UK, without any trials, justifying this statement by saying there is no need, referring to a similar facility in Australia **(**The Journal, 2014**)**[24] - one of the Australian UCG trials which has resulted in a total ban on UCG as of April this year), attempting to use a technology for the first time - in an environment UCG has never been tried before – under water

The Broad Alliance, whose members were fully aware - and following this unfolding disaster in Queensland - assert it is Cluff Natural Resources and Five Quarter, to protect their own investments, who were being picky with the scientific evidence, when neither made reference to the on-going ban in Australia, put in force by an independent panel of scientists, with no vested interest, as the trials had still not proven the latest UCG techniques, proposed for Scotland, using that very technology, could be carried out safely from start to finish, neither made reference to the previous environmental damage that resulted in one UCG trial being shut down within weeks of starting a second UCG trial also ending up in court for causing serious environmental harm.

But most importantly both companies making these statements when it had already been reported just weeks earlier the Queensland government had imposed a 320sq km excavation exclusion zone near the Linc Energy trial warning “property owners should seek advice from The Department of Environment and Heritage Protection (EHP) if they plan to excavate to the dept of 2 metres or deeper within this zone.” **(**EPA 2015**)**[25] as toxic combustion gases were present just below the surface at explosive levels.

When the three private companies involved in the Australian trials failed to report in a timely fashion, at best, covering up serious problems from a UCG trial and breaches of UCG pilot regulation and fleeing the country while the investigation into major problems at the Linc Energy UCG trial at worst, these statements made by these companies prove a level of recklessness that begs the question are either of these companies fit to hold a UCG license, especially as Algy Cluff had already misled the people of Fife when he stated categorically water is not used in UCG operations – yet he told prospective investors “oxygen and steam” are used in the UCG process, not once but twice

Despite these statements the Broad Alliance were following events closely in Queensland and by 10th August 2015 an ABC news report, revealed (Solomons, Willacy, 2015)[26]

> “A study commissioned by Queensland's environment department says an experimental plant operated by mining company Linc Energy at Chinchilla, west of Brisbane, is to blame and has already caused "irreversible" damage to strategic cropping land.
>
> The department, which has launched a $6.5 million criminal prosecution of the company, alleges Linc is responsible for "gross interference" to the health and wellbeing of former workers at the plant as well as "serious environmental harm".

On the same day a report revealed **(**Brisbane Times, 2015**)**[27]

> "Four Queensland government workers were hospitalised while investigating an underground coal gasification plant at the centre of serious pollution allegations.
>
> Documents obtained by the ABC reveal the environment departmental investigators suffered suspected gas poisoning while testing soil at the site of the Linc Energy operation at Hopeland, west of Brisbane.
>
> One of the workers said he was nauseous for several hours and his blood tests showed elevated levels of carbon monoxide.
>
> An expert study commissioned by Queensland's environment department, also obtained by the ABC, says gases released at the plant have caused the permanent acidification of nearby soil"

By October 2015, **(**Robertson, 2015**)**[28] farmer George Bender, who was said to be "proud of his "clean and green" produce, and had won many awards for his wheat" committed suicide, unable to take any more of life due to the effects on his farm and his life by the Coal Seam Gas and UCG operations, with his daughter Helen saying to a government panel

> "On Saturday we buried my father [who was] struggling for 10 years against the CSG industry and Linc Energy."

With the Guardian report going on to say

> "A Chinchilla local, Karen Auty, told the panel credible medical studies had identified problems with exposure to gas, which had led to children in her area for the past two and a half years suffering from nose bleeds, rashes and insomnia from headaches."

When Federal Assistant Health Minister Fiona Nash was asked what she "would do in response to lingering health concerns among residents near Queensland‟s gasfields." she said studies were on going

> "But there‟s no doubt we need to do more," Nash said. "Where there are health impacts, we need the work to be done to show us. I know there is existing work already but we need to build on that to get a clear and proper picture exactly of what these health impacts are.
>
> "And from my view in all of this, we should take the precautionary principle, we should be conservative and things should be on hold until they can be proven not to have an impact, in my view."

UCG Banned In Queensland April 2016

As a result of the Cougar Energy, Carbon Energy and Linc Energy UCG pilots and the resulting environmental disaster in Hopeland as a result of the Linc Energy UCG trial, on April 18, 2016 in a joint statement, Government Ministers, the Honourable Anthony Lynham, and The Honourable Steven Miles revealed, The Palaszczuk Government has moved to ban underground coal gasification because of its environmental impact stating **(**Lynham, Miles, 2016**)**[29]

> "We have looked at the evidence from the pilot-operation of UCG and we‟ve considered the compatibility of the current technologies with Queensland‟s environment and our economic needs.
>
> "The potential risks to Queensland‟s environment and our valuable agricultural industries far outweigh any potential economic benefits," he said.
>
> "The ban applies immediately as government policy, and I will introduce legislation to the Parliament by the end of the year to make it law."

“As a government, we support our resources sector for the jobs and economic growth it generates, but UCG activity simply doesn‟t stack up for further use in Queensland.”

“In addition, our new chain of responsibility laws will provide new powers to require that contaminated sites must be cleaned up.”

Two days later it was reported in the Ilawarra Mercury, (Phelps 2016)[30] farmers affected by the UCG disasters are collectively suing Linc Energy‟s insurers and from the Queensland government stating

“The State Government is the ultimate owner of mineral resources in this state and they are responsible for the granting of licenses to exploit those resources,” Mr Marland said.

“They owe a duty of care to the community that those licenses are appropriately granted, regulated and monitored.”

Why UCG Should Be Banned In Scotland Too

With the Queensland government having now banned UCG completely, based on the evidence from all three pilots, which all resulted in severe environmental damage, one trial forcibly shut down within weeks and the other two trials being decommissioned, with all three private operators charged in court with causing serious environmental damage and breaching environmental safety regulations, this is not the only evidence available which proves conclusively UCG should also be banned in Scotland.

Sepa has admitted it has no way to monitor UCG operations in Scotland

All UCG trials around the world to date have been conducted and monitored onshore. The results of these trials were varied with some of the problems reported being:

- Groundwater contamination with BTEX chemicals
- Land contaminated with BTEX chemicals
- Livestock contaminated with BTEX chemicals
- Underground explosions, which could not be stopped, due to pipes feeding the combustion material into the UCG cavity becoming blocked
    - With the pipes becoming blocked in both the part DTI funded EU trial and the Linc Energy Chinchilla trial
- Subsidence underground and at ground level
- Workers exposed to toxic gases
- UCG cavities fractured by too much pressure leaking toxic gases hydrogen, hydrogen sulphide and carbon monoxide underground, rising to just below the surface to gather at explosive levels across a 320sq km radius in Queensland and toxic gas leaks from the cavity in the Polish trial too.

With one Queensland resident reported as saying (The Australian, Weekend Australian Magazine)[31]

> ""Anyone who has a bit of common sense would wonder about it," …
>
> "You"re lighting a fire down there, pumping all that air pressure in – something"s got to give. I don"t know how anyone could dream they could contain it."

With the Weekend Australian Magazine[31] going on to report

> "In the 16 months since then, they"ve become a lot more enlightened. They"ve learnt that Linc Energy stands accused of fracturing the rock beneath their land and releasing toxic chemicals into the soil, air and groundwater over a six-year period. They"ve read that Linc"s workers were told to cover up the contamination and drink milk to protect themselves. They"ve been told that digging a hole in a paddock might release "potentially explosive and/or toxic and/or asphyxiating mixtures

of gases". They"ve heard the Queensland environment minister, Steven Miles, describe it as "the biggest pollution event probably in Queensland"s history"."

With the two of the three UCG trials in Australia, both running for several years, still managing to cause severe environmental harm, despite being carefully monitored by the Queensland government – how on earth do Sepa propose to monitor a pilot UCG trial, by a company with absolutely no commercial UCG experience under the Firth of Forth?

In response to a freedom of information request[32], on 28th September 2015 to FOI FOI85781 Sepa officials state

- Point 3.2 "at this time, no monitoring plans or processes specifically related to UGC have been developed.

The Ferret, online investigative reporting news website reported in December 2015 in an article headed "Mining for coal gas could cause blasts, fires and quakes, says Sepa" **(**Edwards, 2015**)**[33]

> "Plans to gasify coal under the sea around Scotland could cause pollution, earthquakes, underground explosions and "uncontrollable" fires, according to confidential draft reports from the Scottish Environment Protection Agency (Sepa).
>
> The Scottish Government"s green watchdog admits that it doesn"t know what level of protection its safety regulation can provide against the hazards of underground coal gasification (UCG). The risks were "sometimes unknowable", it says in one report.
>
> The revelations have prompted anger from politicians, community groups and environmental campaigners. They are demanding that the government"s temporary moratorium on UCG be turned into a permanent ban."

The news report went on to say FOI requests had revealed

> "In preparation for regulating the technology, Sepa scientists have drafted reports outlining the potential hazards. A first draft from early this year and a second, marked "confidential" and dated July 2015, have been released under freedom of information law.
>
> Drawing on evidence from UCG facilities in Europe, the US and Australia, the reports list eight things that can go wrong. Groundwater can be polluted by toxins such as phenols, cyanides and radioactivity, they say.
>
> Air can be polluted by highly toxic particles, ash, heavy metals and a series of hazardous gases, says the latest draft. Emissions of the greenhouse gases that disrupt the climate are estimated to be lower than from coal but higher than from natural gas though "large uncertainties remain", it warns.
>
> There is a risk that "induced seismicity" could damage boreholes and surface installations, as well as spread pollution. Underground explosions, which have been recorded abroad, could inflict similar damage, Sepa says.
>
> Igniting the coal underground could lead to "uncontrollable fire", which would worsen water and air pollution. The danger of underground "cavity collapse" could cause subsidence on the surface.
>
> "The fundamental cause for concern with regards to UCG is that the conditions under which the reaction takes place are naturally variable and difficult to know (sometimes unknowable), placing an inherent limitation on process control," says Sepa"s first draft. "This, combined with a number of significant environmental and human health hazards, creates risk."

The more recent draft points out that some of these risks could be reduced if developers drill down to more than 800 metres below the sea, as they plan to do. But it doesn"t say the risks could be eliminated.

There are “significant technological and knowledge gaps”, it warns. Because controls and regulations are still being clarified ”it is not possible at this stage to assess the level of protection they will provide.”

Emails released in response to a freedom of information request also reveal that Sepa was anxious to alter the minute of a meeting with the UK government officials discussing UCG in February 2015. Sepa sought to remove a sentence questioning whether there was “a robust regulatory environment in place”.

The Ferret Report listed the eight hazards of underground coal gasification:

Groundwater pollution	toxic gases and metals could contaminate the ground and possibly find their way into drinking water
Surface water pollution	toxic gases and metals could contaminate the sea and other surface waters
Air emissions	ash, particles, metals and gases could pollute the atmosphere, risking health and worsening climate change
Underground explosion	inflammable gases could be ignited by a spark and explode, damaging boreholes and buildings
Cavity collapse	underground cavities could collapse and cause subsidence on the surface
Seismicity	earthquakes that would damage boreholes and surface installations, as well as spread pollution
Groundwater depletion	other users could be deprived of water, and environmental damage could be caused
Uncontrollable fire	underground coal could burn out of control, causing air and water pollution and risking cavity collapse

With Sepa admitting “The assessment of potential risk requires significant additional work”

With explosions in the UCG trials in Spain and Poland – with the UCG cavity cracking and releasing toxic gases in the Polish trial – just as happened in the Linc Energy trial in Queensland, this proves conclusively this technology is not controllable at levels closer to the surface onshore than that proposed by the Cluff Natural Resources trial under water– and even with government monitoring of the onshore trials major environmental damage could not be prevented.

As onshore trials have been so disastrous it is impossible to go ahead with a UCG trial in Scotland under water as Sepa admit they have no idea how to monitor this trial under water, as this has never been tried anywhere in the world, and are not aware of any country in Europe having developed any safety policies in relation to UCG based on EU directives.

With none of the UCG license holders in the UK having any commercial UCG experience, Sepa and the EA having no experience monitoring UCG onshore, never mind under water, Sepa and the EU unable to figure out what regulations should be in place and no one able to say how this should be regulated in line with EU directives, the Underground Coal Gasification Association in London going into administration and the Queensland government declaring a complete ban on UCG, based on the evidence from their trials over many years - even investors have walked away from UCG in the UK, resulting in Five Quarters, one of the UCG license holders in Scotland going into administration in April this year, despite being given £15million of taxpayers money and a £1billion taxpayer guarantee by the Westminster Parliament, to cover investor losses should it all go wrong.

Even the Westminster UCG group ask the question, given the risks involved and the fact the technology is relatively unproven, should the UK be the first country in the world to roll out UCG **(**UCG Working Group, 2014**)**[34].

The Broad Alliance believes the Queensland government answered that question conclusively in April 2016– UCG cannot be undertaken safely – so much so an immediate ban across Scotland (and the rest of the UK) should also be put in place, with laws to follow– as UCG is so dangerous has even small pilots of UCG, using world leading horizontal drilling techniques can cause irreversible environmental damage and pollute and put endanger the economy, business and those living within hundreds of square kilometres when things go wrong.

It is vital this ban is put in place across the whole of Scotland ass the Kincardine and other UCG licenses in Scotland are issued near densely populated areas, with the real possibility each UCG licenses could leak toxic combustion gases hydrogen sulphide, carbon dioxide and hydrogen from underground up to densely populated areas via honeycombs of old mine workings and fault lines, affecting even our capital City of Edinburgh.

Why Kincardine & the Firth Of Forth Are Not A Suitable Area for UCG licenses

The "UNDERGROUND COAL GASIFICATION ("UCG") POLICY STATEMENT FOR LICENSING BY THE COAL AUTHORITY" **(**UK Government December 2009**)** [35] states

> "The Authority will normally only consider UCG conditional licence applications for :-
>
> □Offshore areas. Offshore licence areas can also include an onshore access strip to facilitate the sinking of exploration boreholes during the conditional licence phase and for sinking directional access boreholes into the offshore UCG area during the operational phase. *(see note 2)*
>
> □Onshore areas, but only where it can be demonstrated that the surface is suitable for piloting this technology. *(see note 3)*
>
> □Areas where there are :-
>
> o no other Coal Authority Mining Licences & Agreements;

o no existing Petroleum Licences;

o no identifiable defence installations; and

o no existing or proposed wind farm sites or other major structures on the seabed.*(see note 4)*

A maximum initial application area of 10,000 hectares. *(see note 5)*

Areas where the Department of Energy & Climate Change, The Crown Estate, The Ministry of Defence or other relevant bodies do not raise objections. Consultation will be undertaken by the Authority with these relevant bodies on receipt of a conditional licence application. *(see note 6)"*

The license conditions state

"Licences will be subject to advertising by the Authority in order to stimulate competition.

The initial term of the Conditional Licence will normally be restricted to a maximum of three years. The Authority will require Conditional Licence holders to undertake further discussions with the Department of Energy & Climate Change, The Crown Estate, The Ministry of Defence and other relevant bodies during the conditional period as they formulate the detail of their operations.

The conditions will include a requirement for the applicant to undertake an agreed programme of works during the term of the Conditional Licence. Failure to complete the agreed programme of works will result in the Licence being revoked unless the Authority can be satisfied that the Licensee is committed to the pilot project.

Where the proposed UCG operation and its ancillary activities have a potential to interact with or damage third party property interests then a condition will be included requiring the Licensee to provide evidence of the existence of a Commercial Agreement between the parties outlining the manner in which any interaction or damage so caused is managed, remediated and funded. *(see notes 8 & 9)*

Further requirements for de-conditionalising a licence in whole or in part will be incorporated into the licence conditions and are set out in more detail in the Authority‟s Model Underground Coal Gasification Licensing Documents."

The September 2004 DTI Report "Review of the Feasibility Of Underground Coal Gasification In the UK" (DTI, 2004)[36] stated

"Firth of Forth UCG Study : A study, entitled "The Coalmine of the 21st Century" has been initiated by Heriot-Watt University with support from DTI, Scottish Enterprise and Scottish and Southern Energy Ltd. Its aim is to undertake a feasibility of UCG in the substantial coal resources of the Firth of Forth This study builds on work already undertaken as part of the initial search for a test site, and will establish whether this area offers prospects for large-scale UCG and power generation. If the one-year study is successful, a prospectus will be produced to attract investment funds in the development of the project."

The duration of the study was 13 months, from March 2004 to March 2005 and the report of study stated **(**Heriot-Watt University, 2006**)**[37]

"The search for a site became a greater challenge than initially expected. Kincardine was soon ruled out because the river narrows to the west of Kincardine Bridge and any UCG operation beyond the initial trial would require the inclusion of onshore resources, parts of which are licensed for CBM extraction.

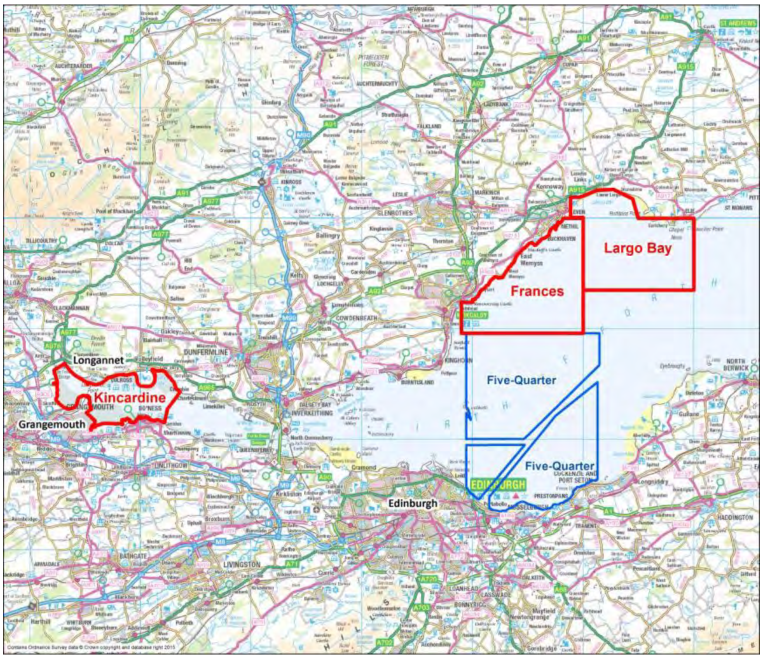
Grangemouth was more promising as the river is unusually wide and the surface banks already have significant industrial activity. However, the previous work had found that the Longannet-Grangemouth area had an unacceptable geological risk, and this was largely supported by the present study.

Some structurally benign areas can be found within the prospect for trial purposes, but large areas are likely to be affected by structural and igneous features which would probably eliminate a commercial scale operation.

As the study progressed, the coal seam area of Musselburgh to the west of Edinburgh was found to be superior on geological and hydrogeological grounds and the best geological option for large-scale UCG production. However, the parallel environmental impact study showed that surface constraints at the shoreline would make access and shore facilities difficult to locate, and any UCG operation would need to be based entirely on offshore platforms. For the other sites, there were more options for the location of shore-based plant, but the geology was less certain, and more data were required to prove whether any of the sites would be suitable for a UCG trial."

The feasibility study concluded

"Four potential regions of the FoF, Kincardine, Grangemouth, Musselburgh and East Fife, were examined as potential areas for commercial UCG. All had commercial quantities of coal potentially suitable for UCG (>20M tonnes), but the first three regions identified above had either data deficiencies, limitations on coal geology or surface constraints."



In a report commissioned by Cluff Natural Resources, (Beltree Limited, 2015)[38] the study looked at an area of interest 2km around the Kincardine license area

On page 5 of the report it says

> "CNR‟s Kincardine licence lies in the Midland Valley of Scotland (MVS) – a southwest-northeast trending basin cutting the central belt of Scotland (Figure 1.1). The MVS is around 80km wide, extends roughly 150km onshore across Scotland and is a major population centre with five of Scotland‟s seven cities lying within it. (Beltree Limited, 2015)[38]

On page 26 of the report it says

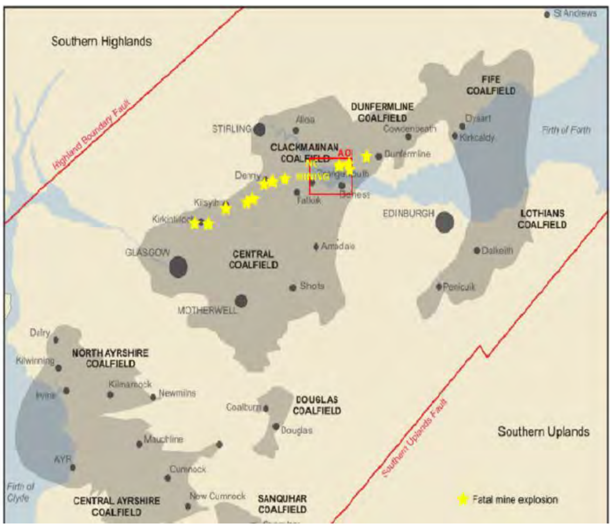
> "Uncharted mine entries and abandoned workings in multiple seams of coal and associated minerals within the Coal Measures should be anticipated wherever they outcrop in the Kincardine UCG license area of interest. Shallow voids, loosely compacted mine waste, and weak roof-supporting pillars within abandoned workings pose a high risk of

rockhead and surface instability and loss of fluid circulation at drilling locations(Beltree Limited, 2015)[38]

Page 26 of the report also reveals

> "The Bowhousebog Coal, in the upper part of the Passage Formation locally attains a thickness of 1.3m between Larbert and Dunmore and several old pits are believed to have worked it at both locations and in the intervening ground.
>
> Abandoned mine workings therefore pose a risk to surface stability and loss of circulation at drilling locations wherever the lower part of the Passage Formation subcrops beneath superficials, and close to the outcrop of the Bowhousebog Coal." (Beltree Limited, 2015)[38]

Page 34 of the report gives a map showing "location of a lineament of fatal mine explosions in workings within Limestone Coal Formation seams in the Central and Clackmannan Coalfields. Data from UK Government statistics summarised by scottishmining.co.uk. Note that a break in the lineament occurs in the axis of the Clackmannan Coalfield where the seams were too deep to be mined but where high gas contents and saturations have reported to have been measured by Composite Energy in exploratory CBM drilling at Airth. (Beltree Limited, 2015)[38]



Page 36 of the report reveals

> "All of the target coals have been worked by traditional mining methods within the project AOI. All except the Upper Hirst have been worked in the east of the licence area where they are at shallower depths. The Upper Hirst seam conversely has been worked in the west – extensively onshore and to a lesser degree under the Firth of Forth" (Beltree Limited, 2015)[38]

Page 41 reveals

> "However, despite the reasonable quality, the seismic lines are widely-spaced in relation to the structural complexity, so borehole tops, fault analyses and mine abandonment plans of Old Coal Workings (OWS) have been key to understanding the structure and filling some of the gaps between seismic lines. Without this supplementary data, seismic faults and the target continuous reflection event segments would almost certainly be mis-correlated. Even with the supplementary drilling and mining data, some areas are of the licence have too poor data coverage to make an unambiguous interpretation" (Beltree Limited, 2015)[38]

Page 44 goes on to say

> "with faults progressively migrating out of the licence to the north and to the south with increasing depth" and "The Midland Valley sill, known from drilling, does not image well in the legacy seismic. Line TOC86M112 tentatively images a flat zone at the appropriate depth predicted by its penetration in the Inch of Ferryton 1 well. It is hoped that reprocessing might strengthen the confidence in this pick and its extrapolation away from well control." (Beltree Limited, 2015)[38]

Page 48 says of possible coal panels for the UCG operations

> "It is important to point out that the identification of these panels is largely based on legacy 2D seismic of insufficient density and resolution to image faulting that can be observed in the mine abandonment plans. It should therefore not be assumed that the panels identified in Figure 4.15 are completely free of faulting or folding of a complexity that might have a negative impact on successful execution of a horizontal UCG well." (Beltree Limited, 2015)[38]

Page 49 says

> "In fact, most of the small faults displayed on the interpretation have throws smaller than 20 m and, if encountered during drilling of a horizontal production lateral, could result in premature termination of the wellbore if the seam could not be found on the other side of the fault. "(Beltree Limited, 2015)[38]

While the people of Scotland are told not to worry this UCG trial will operate at depths much deeper than previous failed UCG trials, this report reveals on page 53, this trial in fact is specifying a minimum depth of 300m up to a maximum of 2000 metres – so Cluff proposes burning coal just 300m below the surface – not as deep as we have been led to believe. (Beltree Limited, 2015)[38]

The Belltree Ltd report conclusions are

> "After collating, reviewing and interpreting the public domain data that is available for the Kincardine licence and adjacent areas, it is concluded that current data density (from boreholes, mine abandonment plans and particularly seismic) may be insufficient to:
>
> - Detect the presence of some barriers to UCG burn progression such as minor faulting which may also compartmentalise the resource;
> - Accurately plan the trajectory of a horizontal well (especially the in-seam land-out coordinates at the end of the build

section, and provide early warning of steering requirements imposed by structural undulations or discontinuities); and

- Characterise faulting in terms of its ability to transmit water and gases without further modelling. (Beltree Limited, 2015)[38]

The academic paper, “The groundwater hydrology of underground coal gasification coupled to carbon capture and storage” states subsidence of the UCG cavity “could” provide the benefit of making the rock in the roof above the cavity “more permeable” up to 60 times higher than the cavity itself P.L. **(**Younger, G. González 2010**)**[39]

With the Belltree Ltd report revealing the minimum depth of the coal being considered for the Kincardine trial being just 300m below the surface, once the UCG cavity inevitably collapses, as Professor Paul Younger who used to be on the board of UCG company Five Quarter states, how close to the surface this rock will become more permeable.

Professor Younger‟s paper is an academic paper and if those calculations are incorrect – and that cavity collapse causes the rock above the cavity to become permeable all the way to the surface then this could allow the waters of the Firth of Forth to access not only the UCG cavity but the honeycomb of interlinked mine workings, charted and uncharted, surrounding the cavity made accessible when the cavity collapses too.

There is no way to support a UCG cavity, as one can in a traditional coal mine, which makes undertaking a UCG project in an area honeycombed with old mine workings and fault lines an unsuitable area for any UCG project – a conclusion the Heriot Watt university feasibility study has already concluded.

While the Westminster government can draw a line on the shoreline for each UCG license – fires and gases escaping from UCG trials do not respect the lines drawn on a map but follow fault lines and permeable rock and gaps caused by old mine workings which would allow the gases from a process that cannot be controlled underground to rise to the surface in a densely populated area.

Cluff Natural Resources stated in January 2016 their UCG plans for Scotland are not “dead in the water” **(**Lammey 2016**)**[40] with the Energy Voice report stating

> “CNR said in a statement it felt there was more support for investment in energy and industry in England, where there is no moratorium on UCG.”

This statement was proven wrong after Five Quarter went into administration just three months later, after investors could not be found, despite the £1billion Westminster government taxpayer guarantee.

The Midland valley faces a UCG-CBM-Fracking perfect storm, with fracking and UCG both known to cause earthquakes in an area with known fault lines and seismic activity before any of these UGE proposals are moved forward – fault lines on which both Scotland‟s ailing nuclear power plants also sit on.

Should millions of tons of coal be set on fire, underground, using a process where operators have proven time and again they have no control over once things go wrong, in an area where fracking operations are taking place to fracture rocks deep underground to release methane gas.

Imagine a combined UCG/fracking/CBM methane underground explosion from the underground coal fires of the UCG trial meeting methane from fracking operations that has seeped through underground fractures and fault lines, the explosion ripping through a honeycomb of coal mines, many not documented, in a densely populated area with two major road bridges, a chemical plant, Rosyth Naval Base, with decommissioned nuclear submarines and the biggest methane tanker in Europe in a densely populated area – a disaster which would make the recent chemical plant explosion in China appear like a small fire work exploding should this very realistic scenario happen.

But the risks do not end there.

The Impact of UCG On The Climate

In the academic paper **"Underground coal gasification with CCS: a pathway to decarbonising industry** (**Younger, G. González 2010**)[39] the former directors of Five Quarter stated

> "Underground coal gasification (UCG) opens up the prospect of accessing trillions of tonnes of otherwise unmineable coal. When combined with carbon capture and storage (CCS), UCG offers some attractive new low-carbon solutions on a vast scale. This paper has several aims: to review key developments in technologies for UCG, CCS and CO2 storage in coal seam voids; to quantify the scale of the opportunity that these technologies open up; .. and to propose a basis on which UCG-CCS can sit at the heart of plans to decarbonise present day industry in a way that dove-tails with longer-term ambitions for an economy based on renewable energy."

They report states in the introduction

> "If UCG can be successfully linked to CCS, then the combined UCG–CCS offering provides a way of harnessing the energy contained within huge untapped coal resource whilst remaining within the ever-tightening targets for reducing CO2 emissions. The requirements for achieving long-term storage of CO2 and the CO2 trapping mechanisms for deep saline aquifers and depleted hydrocarbon fields are well documented"

In section 2 of the UCG technology it states

> "The basic idea is that energy can be recovered from deeply buried coal seams by gasification of the coal in situ. This is readily achieved by introducing hot steam and oxygen or air to the coal via injection boreholes. In a sense, the uncontrolled combustion of coal underground is well known as a result of the many coal fires that have occurred around the world. However, the controlled gasification of underground coal is a different matter."

Over 50 years ago the town of Centralia in Washington State had to be abandoned after a fire at a landfill spread to an abandoned coal mine (BBC 2012)[41].

And Queensland has discovered UCG is not a different matter and a UCG trial has resulted in toxic combustion gases hydrogen sulphide, carbon dioxide and hydrogen leaking across a 320 sq km radius to gather at the surface at explosive levels, resulting in permanent damage to prime farmland and farmers being instructed not to excavate below 2m – something no traditional coal mine has caused.

Section 2.1 of the report goes on to say

> "The target coal seam can be on-shore, near-shore or off-shore. In all three cases, a fundamental requirement is the ability to accurately and remotely direct drilling equipment to create the network of gasification channels, injection wells and production wells for a UCG operation"

This requirement cannot be met in the Midland Valley as the Belltree report conclusions state clearly

> "After collating, reviewing and interpreting the public domain data that is available for the Kincardine licence and adjacent areas, it is

concluded that current data density (from boreholes, mine abandonment plans and particularly seismic) may be insufficient to:

- Detect the presence of some barriers to UCG burn progression such as minor faulting which may also compartmentalise the resource;
- Accurately plan the trajectory of a horizontal well (especially the in-seam land-out coordinates at the end of the build section, and provide early warning of steering requirements imposed by structural undulations or discontinuities); and
- Characterise faulting in terms of its ability to transmit water and gases without further modelling.

In section 3.2 of the report “Storage Potential” (for CO2) the report states

> “For the reasons given in Section 2.3 above there is still a question over the precise volume of CO2 that can be stored in the UCG coal void. Suppose, for the sake of argument, that 50% of the CO2 arising can be stored back in the void space. If the aspiration is to target (say) 4 trillion tonnes of coal for UCG operations, that would translate into 12 trillion tonnes of CO2 arisings, with (say) 10 trillion tonnes of CO2 being captured (if CCS is deployed universally), and 5 trillion tonnes being stored in UCG void space. Compared with current levels of CO2 emissions world-wide of around 27 billion tonnes per year, we are therefore looking at around 200 years of CO2 storage capacity at current emission levels, which is getting close to the figures usually quoted for CO2 storage capacity in saline aquifers. From a global perspective, therefore, the UCG–CCS concept deserves more serious consideration alongside some of the other more prominent carbon management proposals.”

The Environmental Protection Agency in America states on their website

Increasing greenhouse gas concentrations will have many effects

Greenhouse gas concentrations in the atmosphere will continue to increase unless the billions of tons of our annual emissions decrease substantially. Increased concentrations are expected to:

- Increase Earth's average temperature
- Influence the patterns and amounts of precipitation
- Reduce ice and snow cover, as well as permafrost
- Raise sea level
- Increase the acidity of the oceans
- Increase the frequency, intensity, and/or duration of extreme events
- Shift ecosystem characteristics
- Increase threats to human health

These changes will impact our food supply, water resources, infrastructure, ecosystems, and even our own health.

- The extent of future climate change depends on what we do now to reduce greenhouse gas emissions. The more we emit, the larger future changes will be.

In an article in The Bulletin of Atomic Scientists it states (House 2010)

It's been estimated that around 4 trillion tonnes of otherwise unusable coal might be suitable for underground gasification. If true, then the economic development of this process would expand coal reserves by a factor of about five. Such an expansion would be both good and bad. From the perspective of maintaining a prodigious and affordable energy supply, gasification would be a boon. But from a climate change perspective it could be a nightmare. If just current conventional coal reserves were fully combusted, the concentration of atmospheric carbon dioxide would approximately double. But if an additional 4 trillion tonnes were extracted without the use of carbon capture or other mitigation technologies, atmospheric carbon-dioxide levels could quadruple--resulting in a global mean temperature increase of between 5 and 10 degrees Celsius.

The DTI report on proposals for UCG in the UK states that carbon capture would be required for any UCG operations in the UK.

Yet the "**UNDERGROUND COAL GASIFICATION ("UCG") POLICY STATEMENT FOR LICENSING BY THE COAL AUTHORITY (**UK Government December 2009**)** states clearly in Notes on Policy License Area where one of the assumptions the Authority has made in note 1.6

"The process is outside the remit for carbon capture and storage."

Yet in the article New Scientist Journal “Fire in the hole: After fracking comes coal” (Pearce 2014)[1]

Pearce states

> “The Intergovernmental Panel on Climate Change recently reckoned that the world needs to limit total emissions of carbon, from now on, to less than half a trillion tonnes just to keep global warming below 2 C. Most climate analysts agree even burning a large fraction of conventional fossil fuel reserves would produce unacceptable warming, let alone what could be released by UCG.”

In the Biggar Ecomonics Report, commissioned by Cluff Natural Resources, in section 3.2 Drilling it states

> “The drilling of panels will be a continuous operation to supply the oxygen required for the gasification process and to extract the products of this process. Throughout the thirty-year life span of this project, it is anticipated that 108 panels would be drilled. Each panel would have a life span of approximately three to five years before it is decommissioned.”

Cluff Natural Resources stated in 2013, just five of their UCG license areas hold **1.75 billion tons of coal**.

This is the equivalent of 680 miners taking 538 years to mine 1.75 billion tons of coal, based on the UK record of 3.25 million tons of coal mined in a single year at the Daw Mill coal mine – which ironically shut in 2013 because of an underground coal fire.

Former Academic Dr Harry Bradbury, and former CEO of Five Quarter, in an article entitled “FIVE-QUARTER: “WIN-WINNING” SOLUTION FROM COAL on the Natural Gas Europe website states there are **three trillion tons** of coal in the North Sea and he says “getting progressively smarter about how we can access those assets is **a real prize for us.**

The DTI estimates there are a further 300 years worth of UCG coal onshore.

If these values are combined and all this coal was burned underground without capturing any of the CO2 this would result in UCG operations in Britain alone could cause a global mean temperature increase of between 5 and 10 degrees Celsius.

Section 6.2 of the report " Potential Contribution to the Scottish Chemicals Sector" it states

> "CNR has an interest in several UCG licence areas around the UK but has chosen to develop the Kincardine project first. One of the main reasons for this is because the Kincardine site is located very close to Grangemouth, which is a potential end user of syngas."

Section 7 SYNGAS USE – POWER GENERATION states

> Should UCG be widely adopted across the UK it is considered likely that the majority of syngas produced would be used in new build, high efficiency gas turbines for the production of primary electricity. There is a legal presumption that any new build generation capacity built to consume UCG derived syngas would have to include CCS or at least be CCS ready.

Section 7.1 The UK Energy Market states

> The introduction of the 2008 Climate Change Act means that the UK Government is now under a legally binding obligation to reduce the UK‟s greenhouse gas emissions by at least 80% (from the 1990 baseline) by 2050

Section 7.3 Kincardine Power Generation states

> "The economic impact of the construction phase would depend on the amount of capital expenditure required to develop a new power station. It is understood that this could amount to around £250 million excluding the cost of any associated CCS infrastructure which would be required to transport CO2 from the UCG production site to the proposed Feeder 10 pipeline which is planned to take CO2 from the central belt of Scotland to the Goldeneye CCS project off Peterhead

Section 7.4 UK Opportunity for Syngas Power Generation"

> "The development of a 300MW power plant in the vicinity of the Kincardine project would represent a small proportion of the opportunity presented if the full UK UCG resources were utilised."

> "The Kincardine UCG project is based on a site with an estimated coal consumption of 1 million tonnes per annum. This production is expected to be sufficient to produce enough syngas to power a 300MW power plant."

So the Kincardine UCG trial, the Biggar Economics report states will

> "transport CO2 from the UCG production site to the proposed Feeder 10 pipeline which is planned to take CO2 from the central belt of Scotland to the Goldeneye CCS project off Peterhead"

On the Peterhead CCS Project factsheet it states on November 25 the Westminster government cancelled funding to develop the Goldeneye CCS project of Peterhead.

This means the Kinardine UCG project has no CCS solution, with the Biggar Economics report completely ignoring all costs associated with CCS in the economic case.

In response to the Committee on Climate Change report, published just three days ago, the government response states

> "Moreover, the Government welcomes the CCC"s primary conclusion that shale gas development at scale – i.e. at production stage - is compatible with carbon budgets if certain conditions, set out as three "tests", are met,"

The government does not state it is not just fracking that will contribute to CO2 emissions in the UK as it has also issued over 20 UCG licenses with plans to initially burn billions of tons of coal underground across the UK without capturing any of the CO2 as there is no CCS solution and the government have put in place a loophole which allows none of the CO2 to be captured from UCG production if the syngas is used for anything other than power production e.g. chemical feedstock, fertilizer production.

Environmental Consultant, Paul Mobbs, in an email stated in response to the report and the governments" response

> "the CCC have completely ducked the issue of fugitive methane emissions.
>
> Yes, they refer to some recent research studies on the issue, but as part of their calculations they're still using the data from "reduced emissions completion" studies in the USA.
>
> Recent peer-reviewed studies on this data has shown that it is flawed because the methane sensor used doesn't work under all test conditions -- and the data from the Allen study, the standard data source used, demonstrates that it was not sensing high methane releases for some of the time.
>
> The problem with the sensor has been known publicly for about 12 months, and within the industry for much longer. In fact the failure of

> the measuring equipment goes some was to explaining the difference between "inventory analysis" studies used by the industry, and the recent studies of actual gas concentrations which discovered high methane emissions.
>
> All-in-all then, the report is a move on from the blinkered approach of DECC's 2013 Mackay-Stone report. It does have some interesting conclusions -- such as the fact that current oil and gas regulation standard in Britain can't meet the emissions ceiling necessary to meet the UK's carbon budget.
>
> However, due to its failure to reflect the most recent studies on fugitive emissions form the US, its analysis is deeply flawed. It relies upon data which is know to be significantly in error from actual emissions in order to arrive at its conclusions.
>
> Therefore the CCC's report fails to adequately identify the hazards to the climate from unconventional oil and gas exploitation in Britain.

And that is before we factor in billions of tons of coal burned underground without capturing any of the CO2 at the same time.

Conclusions

The Broad Alliance concludes the evidence of the disastrous damage to the environment by UCG trials around the world prove conclusively UCG should be banned in the UK, based on the long term pilots in Australia, which used the same technologies proposed for the Kincardine pilot which have likely caused the biggest environmental disaster in Queensland‟s history, resulting in an outright ban on all UCG earlier this year.

The Heriot Watt feasibility study stated Kindardine and most of the UCG sites considered in Fife are unsuitable, Kincardine definitely being unsuitable for UCG and even the report commissioned by Cluff Natural Resources, published in November 2015 by Beltree Limited concluding there is insufficient data available for the Kincardine pilot this alone proves the UCG plans for Scotland are not viable.

The report reveals the Kincardine pilot is based on coal reserves starting from just 300m below the surface and as academic experts state it is inevitable the UCG cavity will collapse and the rock above the cavity, up to 60 times the height of the cavity will become more permeable, this could result in the Waters of the Firth Of Forth seeping into the UCG cavity causing an underground explosion, in an area honeycombed with coalmines and with known and unknown fractures meeting methane from surrounding fracking and coal bed methane operations underneath two road bridges and around a chemical plant, Rosyth naval dockyard, which holds decommissioned Nuclear Subs and the biggest methane tanker in Europe in a densely populated area.

And with no CCS solution for any UCG plans for the Kincardine project – when the DTI report stated all UCG plans for the UK must have a CCS solution again this proves UCG should not go ahead, especially as the UCG plans for the UK, with a convenient loophole stating none of the CO2 need be captured if the syngas is not used for power production, this will definitely result in the UK UCG energy strategy breaching climate change targets not only for the UK but for much of the world – and definitely proves the CCC report published this week, which made no mention of the UCG contribution to UK CO2 emissions and climate change targets does not provide the full unconventional gas CO2 emissions and the impact on global climate and UK climate emissions.

The Broad Alliance believes the evidence from Australia and the information provided in this report alone proves conclusively that UCG should be completely banned by the Scottish Government, especially as the Biggar Economics report, commissioned by Cluff Natural Resources, putting the economic case for UCG completely ignored the colossal cost of CCS and any risks and associated costs to the environment, local people and industries surrounding the proposed Kinardine UCG project and all the other UCG areas licensed in Scotland.

This is just part of the story and as the Broad Alliance reserves the right to submit further evidence as and when it becomes available to ensure the Government investigation to decide if UCG should be allowed to go ahead in Scotland has the fullest information available before making any decision on this matter to ensure the Scottish Government makes the right decisions on behalf of Scottish Communities.

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I-7 Cluff Natural Resources

In advance of interview, Andrew Nunn provided the following (brackets() are CG edits used to enhance comprehension):

Meeting with Andrew Nunn, Chief Operating Officer, Cluff Natural Resources Plc

Scottish Government Underground Coal Gasification Study

Thank you for agreeing to meet with me on Thursday, 30th June at 1.30. From previous interviews, I estimate that this will take around 90 minutes, subject to the time you have available.

The main topics which I would like to cover include:

- **Your opinion, overall view and any concerns of UCG.**

  - *Deep UCG has been demonstrated at pilot scale to be a potentially viable method for producing SYNGAS from coals for electricity or petro-chemical feedstocks with environmental impacts which can be significantly lower than conventional coal mining and approaching the footprint of conventional natural gas production.*

  - *The UK is particularly attractive for UCG as much of the suitable coal is at significant depth and located offshore – allowing potential offshore developments in the longer term.*

  - *Demonstration of scale up to commercially attractive production rates has not been achieved in recent times (regulatory, technological, fiscal and energy price regime have all moved on since Angren and other large scale Soviet UCG projects which were operational in the 1950/60's) and is a key risk to any future development.*

  - *Public and Government/Regulator knowledge of UCG is extremely limited and not helped by stated positions on absolutes with respect to risk – ie* ***"Unless it can be proven beyond doubt that there is no risk to health, communities or the environment, there will be no fracking or UCG extraction in Scotland".*** *We view this as a an ill judged approach to policy making and suggest it would preclude everything from farming to petrol stations if applied consistently across the board.*

  - *In the end UCG is a tool – when applied properly in the correct geological setting the achieved results are entirely acceptable and the overall risk profile is not significantly different to conventional oil and gas production (ie see Carbon Energy / Alberta Synfuels / Solid Energy). Where geological understanding is limited or corners are cut on engineering or operational oversight then UCG has the potential to* *produce undesirable outcomes (ie alleged incidents around Linc Energy and some early US R&D trials)*

- **The conditions under which you consider UCG could be viable and operated successfully**

  - *The DECC/DTi studies clearly set-out the conditions under which UCG should be conducted in the UK – this includes some specifics around depth of operations and interaction with historical mine workings. The DTi/DECC reports also set out a comprehensive risk assessment methodology for UCG projects.*
    - *A copy of all reports produced by the decade long DTi/DECC study into UCG are included on the provided USB stick.*
  - *Recent examples in Australia would not have progressed if similar criteria were applied (all shallower than the recommended 600m depth restriction) and many UCG trial projects with less conservative parameters than those proposed for the UK have proceeded with limited or non-measurable impacts.*
  - *It is likely that any commercial scale UCG project will require CCS to meet certain climate change objectives. The carbon capture part is not considered to be a significant technical challenge however any future UCG industry may be reliant on access to 3rd party CO_2 storage facilities, or CO_2 based EOR projects, such as those currently being proposed in the North Sea. However given the long lead times for developing a UCG project it is likely that the development of suitable storage facilities would need to occur in parallel with the UCG projects.*

Your views on:

Global/(climate) context

- *UCG is a coal based fossil fuel and produces CO_2 at both the point of production and potentially at the point of consumption, with an unabated footprint somewhere between natural gas and coal when used for generating electricity.*
- *However it is recognised that UCG derived SYNGAS is particularly suitable for pre-combustion CO_2 separation, using commercially available scrubbing technologies, due to high CO_2 concentrations and operational temperatures and pressures at the point of production.*
- *A recent DECC report concluded that when SYNGAS produced by UCG was used for electricity generation in a gas turbine fitted with post-combustion CCS technology then the overall footprint could be close to half of that achievable with abated natural gas. A draft copy of this report is included on the provided USB stick.*

- *A key enabler supporting an emerging UCG industry is the development of viable CO_2 storage facilities in the UK which seems more distant following withdrawal of the CCS competition by the Westminster Government – although certain projects such as Summit Power's surface coal gasifier fitted with CCS is receiving significant financial support from the Scottish Government and the Teesside Industrial CCS project still seems to be progressing.*

The energy policy context

- *While UCG could play a significant role in electricity generation, assessing it entirely within the context of energy policy is short sighted and doesn't take into account the potential of UCG to provide feedstocks for the petrochemicals sector, clean burning liquid fuels, fertilizers for agriculture or to become a significant source of hydrogen for fuel cells etc.*

- *While it is recognised that renewables have an important and increasing role to play in the energy mix, the need for renewable generation to be supported by fossil fuels, preferably gas, for balancing fluctuations in supply and demand have not been adequately communicated or conveniently ignored in the debate over our energy future.*

- *A UK based UCG industry has the potential to provide both surety of supply and further diversifies the UK's energy mix which would aid in wider issues around security of supply.*

- *Along the same lines, our increasing reliance on imported gas to heat our homes, cook our food and support Scottish industry is also overlooked and there is little written about how much extra renewable capacity would be required to completely replace gas as the primary energy source for domestic and industrial heating.*

- *UCG has the potential to provide a locally produced feedstock or industrial fuel gas for Scottish businesses local to our proposed UCG projects – this would displace grid quality natural gas produced from the North Sea and freeing it up for domestic heating and cooking.*

The geological context – specifically Kincardine licence area

- *The Kincardine area is particularly suitable for early stage R&D and modest scale commercial UCG production for a number of reasons:*

    - *Geology is well understood by comparison to many other areas – history of coal exploration & mining + oil and gas exploration provides significant datasets including drilling, geotechnical, geochemical, groundwater and seismic data.*

- *Coal quality is appropriate for UCG, coals are relatively thin and generally separated from each other and the surface by a very low permeability sequence.*

- *Coal located offshore can be accessed from drilling locations onshore.*

- *Groundwaters within, and overlying, the coal bearing strata levels are highly saline and naturally contaminated with a range of organic and inorganic contaminants due to long residences times in contact with coal bearing strata:*

  - *Both the above low permeability formations and water quality issues mean(s) any potential impact on deep groundwater is (not) likely to be insignificant. () CG edits*

- *Historical mining and associated degradation of near surface water quality restricts potential abstraction of near-surface waters for agricultural or potable use.*

- *Composite/Dart Energy has already locally demonstrated the ability to steer long horizontals in coal seams at depths of around 1,000m – this is a key factor in the construction of commercial sized UCG panels.*

- *If any potential residual subsidence associated with the gasification panel is realised (models suggest 10-25mm in an extreme worst case) it will be restricted to offshore and not impact on established infrastructure.*

- *Access to major brownfield sites adjacent to the coast including Longannet & Grangemouth which have established HGV infrastructure, industrial baselines for noise and light impacts and extensive monitoring baselines for groundwater and air quality.*

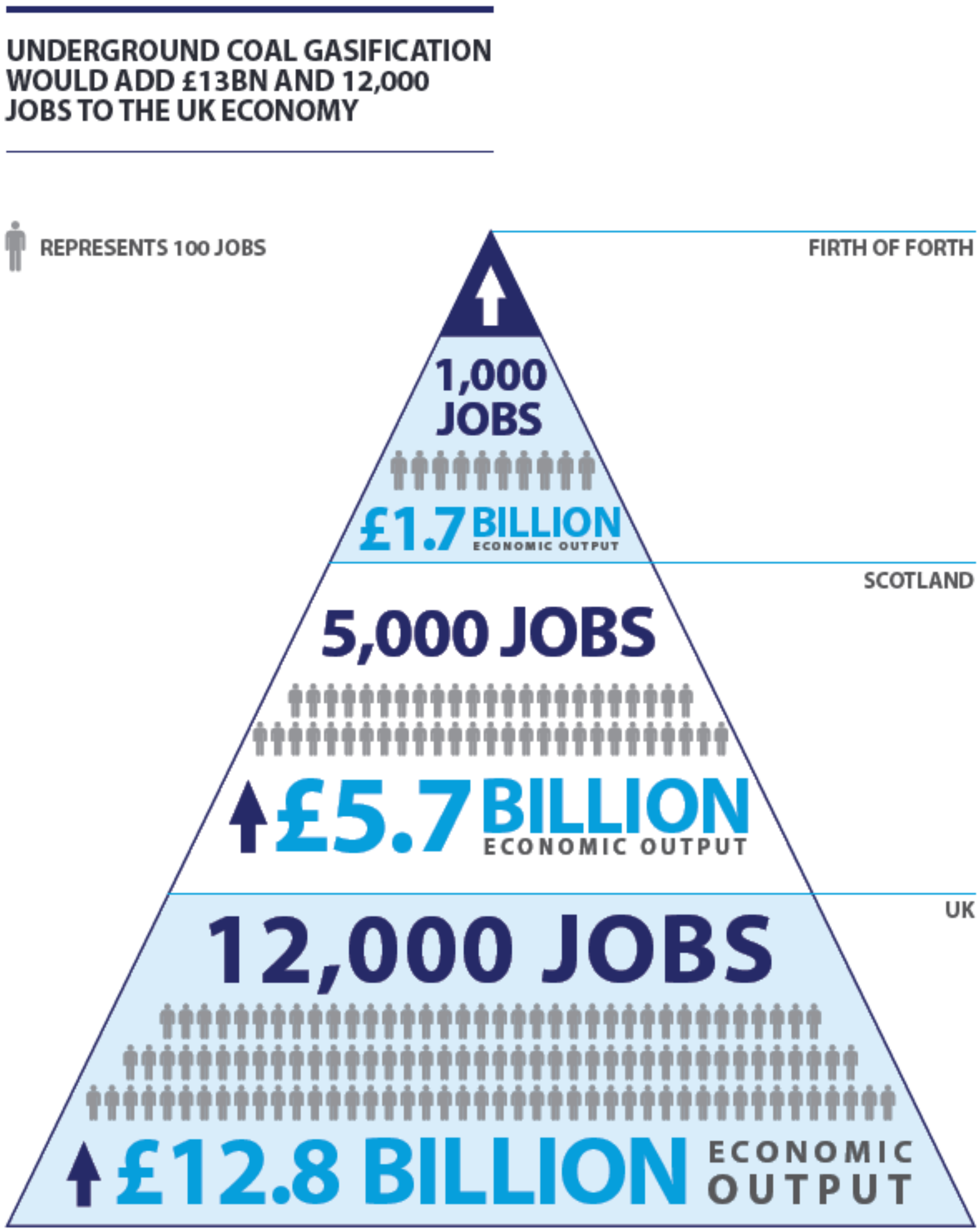
- *Ready-made customer base for SYNGAS products*

- *Potential access to proposed future CCS infrastructure – Feeder 10 pipeline and Goldeneye/Captain CCS projects*

Economic/employment context

- *Cluff commissioned a report from respected Scottish based Biggar Economics outlining the potential economic and employment impacts of Scotland achieving first mover status for a UK based UCG industry including the potential for exporting skills & knowledge to support a global UCG industry – summarised below:*

  - *A copy of this report is included on the provided USB stick.*



Community context

- *While community concerns about new projects are perfectly understandable, it is our view that the general public have been poorly served by Scottish Government communications around its energy policy and significantly misle(a)d by anti-fracking /anti-UCG campaigners over both the very real requirements for fossil fuels to support the expected quality of life (ie surety of energy supply and access to hydrocarbon based products) and the potential risks / benefits and impacts which are likely to be associated with properly designed, operated and regulated UCG project.*

Environment and h&s (general & regulatory) context

- *The current goal setting regulatory system with respect to most HS&E issues is inherently suitable for regulating UCG projects – what appears to be lacking is a suitably qualified and experienced technical resource within the various regulators available to assess and monitor innovative projects leading to an overly conservative, rather than pragmatic, approach.*

- *The Health and Safety Executive has taken a pro-active approach to date and has updated its guidance around borehole construction and other issues to ensure UCG is captured.*

Planning system/process context

- *The current local authority led planning system is not fit for purpose when it comes to determining projects of potentially national significance, especially those deemed 'controversial'*

- *Insufficient technical ability at the local authority level to assess potential impacts, risks and benefits of complex and/or innovative projects which fall outwith the usual traffic / visual / noise / dust aspects*

- *Lack of clarity over primacy in terms of regulatory roles – ie should SEPA (who should have greater technical ability and resources) have the final say on issues relating to groundwater through the existing permitting system rather than it being part of the local authority planning system?*

- *Political interference in the planning system is deterring potential investment into energy projects.*

Technological/Operational context/capabilities to exploit the resource?

- *The vast majority of both the technology and the skills required to operate a UCG project exist within the UK and especially Scotland:*

    - *Drilling is a standard onshore oil and gas operation – existing support and supply chain within the UK and Aberdeen in particular*

    - *Casing design and metallurgy, cement, coil tubing operations and instrumentation from offshore HPHT, sour gas and high temperature geothermal projects are all directly applicable to UCG*

    - *Surface infrastructure required to clean-up and process the gas and any produced water at the surface is again similar to many processes already operated within the Grangemouth facility.*

- *All appropriate required skills to develop and operate a UCG project are available within the UK and particularly Scotland. The experience resides within our globally recognised oil and gas industry and within our* *petrochemical sector and their associated supply chains and consultancy support networks.*

Other aspects of significance?

Given the above (context), what for you is the most compelling aspect determining the way forward…and why?

- *Producing energy locally, whether by UCG or other forms, and taking responsibility for our own consumption rather than displacing our environmental liabilities to geographies where we have no control over HSE, employment or human rights standards at the point of production has to be an inherently better option than continued over-reliance on imports.*

- *The Kincardine project is the ultimate expression of localism where SYNGAS (could be) produced and consumed locally by a highly skilled local workforce and could prove to be a sustainable model for a circular industrial economy which could be rolled out to other UK industrial hubs such as Teesside and Port Talbot.*

What conclusions do you draw about UCG?

- *UCG could be a potentially significant UK based supplier of clean fuel gas for electricity supply and industrial heat or as a valuable feedstock (to) support a significant UK based petrochemical industry.*

- *Scotland was ideally placed to become a leader in the UCG industry, drawing on extensive local highly skilled workforce, cutting edge engineering and technology and established supply chain which currently supports the offshore oil and gas sector and the local petrochemicals industry.*

- *Public, political and regulator perception are key risks which need to be addressed prior to the establishment of a UCG industry and until these issues are resolved and developed into a coherent supportive policy regime the required financial support from the investment community will not be realised.*

What would you recommend that Government do?

- *Establishing a UCG project is a capital intensive process and without clear supportive policy from government that investment will not be made available.*

- *This supportive policy should be grounded on sound scientific evidence (which is already available from previous DTi/DECC studies which are included on the provided USB stick), covering both the requirements for the project in a national context and a clear assessment of the potential and perceived risks and how they are controlled through the existing* *regulatory regime, which can then be widely communicated to the various stakeholder groups – unfortunately the current Scottish Government has a poor reputation within the investment sector for producing sound evidence based policy given it has ignored its own expert panel on Shale Gas and a global scientific consensus on GM Crops.*

- *The path to a commercial UCG project is a series of steps including a small scale demonstrator project, similar to that being proposed by CLNR, and commercial projects are scaled up over a number of years. However no company is going to invest in a demonstrator if there is not a clear commitment to support a commercial project should all the pre-agreed KPI's be met at each stage of the process.*

- *Therefore it is our view that the Scottish Government should:*

  1) *Abandon the completely inappropriate and unworkable 'proven beyond doubt' stance and take a more pragmatic and realistic risk based approach to new projects including UCG.*

  2) *Set out a clearly defined scope and timetable for the studies to be completed under the UCG moratorium along with a firm commitment to lift the moratorium when the studies indicate a risk profile in-line with other accepted land based industrial processes such as petrochemicals and oil and gas production.*

  3) *In conjunction with industry, agree a staged UCG development process with various KPI's at each decision gate along with a commitment that a policy supportive of UCG development will be maintained as long as the KPI's are achieved.*

  4) *The Scottish Government should take responsibility for approval of nationally significant infrastructure projects at Scottish Government level to ensure a cohesive approach to energy and industrial policy delivery.*

An approach similar to that taken in South Australia when producing their Roadmap for Unconventional Gas Projects (included on the memory stick provided) and building on the existing research into UCG would be warmly welcomed by industry, investors and go a long way to ensuring that other stakeholder groups are better informed on many aspects of the industry, it's potential contribution to society and the legislative and regulatory regime.

Campbell Gemmell
27 June 2016
Canopus Scotland

Andrew Nunn
28 June 2016
COO – Cliff Natural Resources

Andrew Nunn also provided a number of useful documents:

1. The Australian UCG pilot experience: A review of Carbon Energy"s UCG Pilot facility at Bloodwood Creek, Queensland, Australia. Cliff Mallett and Anne Ernst, 26th Nov 2014

2. Cluff Natural Resources Deep Offshore Coal Gasification presentation Stockton November 2015

3. Draft Environmental Impact Report for the Proposed Underground Coal Gasification Pilot Project, Secunda, Mpumalanga Province. For public review. A project of SASOL Synfuels and SASOL Mining, February 2009, by Bohlweki SSI Environmental

4. Application for Rectification i.t.o. Section 24G of the National Environmental Management Act of 1998 (as amended) for the Unlawful Commencement of Listed Activities for Underground Coal Gasification: Pilot Plant Phase 1, near Amersfoort, Mpumalanga. Draft
   Eskom Holdings SOC Ltd, DEA ref 14/12/16/3/3/1/54 October 2013

5. Environmental Scoping Report for the Underground Coal Gasification Project and Associated Infrastructure in support of co-firing of gas at the Majuba Power Station, Amersfoort, Mpumalanga. Draft
   Eskom Holdings SOC Ltd, DEA Ref 14/12/16/3/3/3/61 DMR Ref: MP 30/5/1/1/2/10031 MR, October 2012

6. AFRICAN CARBON ENERGY (PTY) LIMITED
   Air Quality Specialist Assessment for Underground Coal Gasification and Gas-Fired Power Generation Project. REPORT
   Report Number: 13615077-12437-6, Submitted to: Etienne Roux, Golder Associates Africa (Pty) Ltd, January 2014

7. Environmental Management Programme February 2014 AFRICARY (PTY) LTD, UCG DRAFT EIA REPORT APPENDIX J
   Environmental Management Programme for Underground Coal Gasification and Power Generation Project near Theunissen. REPORT
   Report Number: 13615077 -12329 -5., February 2014

8. AFRICARY HOLDINGS (PTY) LTD
   Underground Coal Gasification and Power Generation Project Near Theunissen, Free State Province.
   Africary and Golder Associates, July 2013

9. AFRICAN CARBON ENERGY (PTY) LTD
   Final Scoping Report: Underground Coal Gasification and Power Generation Project near Theunissen.
   Due date for public comment: 26 September 2013

10. Need and Economics of UCG in Alaska.
    Estimated economics of the CIRI Underground Coal Gasification

Facility, Beluga Alaska, January 29, 2010, Jeremy Fisher, PhD, Synapse Energy Economics.

11. Viability of Underground Coal Gasification in the "Deep Coals" of the Powder River Basin, Wyoming.
Prepared for the Wyoming Business Council Business and Industry Division, State Energy Office, GasTech, Inc., Casper, Wyoming, June 2007

12. Groundwater Pollution from Underground Coal Gasification, Lui Shu-qin, Li Jing-gang, Mei Mei, Dong Dong-lin. School of Chemistry and Environmental Engineering, China University of Mining & Technology, Beijing 100083, China, 2007.

I-8 Health and Safety Executive (HSE)

Onshore/unconventional guidance from HSE in conjunction, for England, with EA‟s environmental regulatory role is set out in (HSE 2012): http://www.hse.gov.uk/aboutus/howwework/framework/aa/hse-ea-oil-gas-nov12.pdf

I-9 UK Onshore Oil and Gas
Ken Cronin

The following information was provided after the interview.

The Industry‟s community benefit scheme is enshrined in UKOOG‟s community engagement charter, which can be found at: http://www.ukoog.org.uk/images/ukoog/pdfs/communityengagementcharterversion6.pdf

An explanation of how the pilot schemes work is given in the UK Government consultation on the shale wealth fund paras 3.4 to 3.8. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/544241/shale_wealth_fund_final_pdf-a.pdf

Annex 2C
Other contributors

State environment staff in Queensland, NSW, Victoria and South Australia.
I am especially grateful to Mark Gifford, Chief Environmental Regulator for the NSW EPA for his various inputs and initial lessons learned/community outrage webinar produced in 2015.

Legal representatives in Australia, including prosecutor Professor Christine Trenorden and other environmental lawyers in Adelaide, Melbourne, Newcastle, Brisbane and the Environment Agency of England.

Staff at the Newcastle Institute for Energy and Resources, Newcastle, NSW and CRC CARE colleagues there.

Charles Godfray, University of Oxford.

Profs. Paul Younger and Susan Waldron, University of Glasgow.

Prof. Sir Jim McDonald and Prof. Mark Poustie, University of Strathclyde.

Dr. Miroslav Angelov, EU Commission, DG Env.

Dr. Andrea Strachinescu, DG Energy.

Dr. Andrzej Jagusiewicz, former Chief Inspector of Polish State Inspectorate of Pollution.

Prof. Piotr Czaja, AGH University, Krakow.

Chair of the SEA, Colin McNaught.

Prof. Louise Heathwaite, SG CSA.

I also spoke informally with and received inputs from members of a number of community groups from Leith, Musselburgh, Airth and Stirling.

Independent Review of Underground Coal Gasification – Report

Campbell Gemmell

Annex 3

A report to…The Scottish Government, Edinburgh 2016

Annex 3

UCG Operations and Sites

UCG operations have been undertaken in the following locations/cases (more or less in chronological order):

Time and timescale	**Name of site, Location, country**	**Operator**	**Comment, weblink, ref**
From 1912, Northumbria; Newman Spinney/Bayton – 1949/50; 1958/9),	Northumbria; Newman Spinney/Bayton – 1949/50; 1958/9),	Gibb and Partners	NS trial was in ……
1947-60; (1973-89)	Gorgas Creek, Alabama ,USA	US Bureau of Mines	Stephens, et al. 1985
1920s-50s	Russia/Uzbekistan/Ukraine/Azerbaijan) , including Yuzhno-Abinskaya gasification plant at Kuzbass, Siberia	Linc Energy	Test and production sites, ongoing since 1955. Gasification of a bituminous coal in Siberia at Kemerovo, 1.3-3.9m thick. Walker 1999.
1961 to date	Yerostigaz plant, Angren, Uzbekistan	Linc Energy http://www.lincenergy.com/acquisitions_yerostigaz.php	Lignites between 130-350 m depth. Producing since 1961; 1M cu m/d of syngas
1973-79 sequentially; H4 for longest 77-9.	Hanna 1, 2, 3, 4 , (also some references to Rocky Mountain 1,2, 3..) Wyoming, USA	Laramie Energy Technology Center/USDOE	Stephens, et al., 1985, Boysen et al 1990 and Creedy et al 2001. Generally c 100m depth operations in this part of Rockies.
1976-79 sequentially	Hoe Creek 1,2,3 – Campbell County, Wyoming, USA	Lawrence Livermore National Laboratory (LLNL) /USDOE	Wang, F.T, et al., 1982 Stephens, et al. 1985
1978-86	Thulin, Belgium	Belgian/German JV	Trial at > 860m;

(FoE quote 82-4) Purdue 1982-85		Duration– 12 days Institut pour le Development de la Gazeification Souterraine, Belgium	thin seam at 1000m. High CV gas Chandelle, V, 1986, Overview About Thulin Field Test, Proceedings of the Twelfth Annual Underground Coal Gasification Symposium, DOE/FE/60922-H1.
1979	Pricetown, West Virginia, USA	Morgantown Energy Technology Center/USDOE	Stephens et al., 1985a
1979	Rawlins 1, 2 – Wyoming, USA	Gulf Research and Development Company/USDOE	Stephens et al., 1985a
1981, 1985 - 86 Purdue 1983-1984	Initially at Brauy-en-Artois, and later at La Haute Deule, France	75 days. Production well plugged by particulates and tar, terminating the tests. Groupe d'Etude de la Gazeification Souterraine, France	Coal seam depth 880 m Gadelle, C., et al., 1985, Status of French UCG Field Test at La Haute Deule, Proceedings of the Eleventh Annual Underground Coal Gasification Symposium, DOE/METC-85/6028 (DE85013720).
1983 - 2014	Leigh Creek, South Australia	1983 – prefeasibility for South Australia Department of Mines and Energy 1985 – Golder Associates report of viability of UCG at Leigh Creek 2014 – Australian Minerals Consultants (AMC) report of feasibility.	Mothballing of Port Augusta power plant connected to fate of UCG/mine projects
1984-5 (Purdue	Centralia Tono A, B - Washington, USA	Lawrence Livermore National Laboratory (LLNL) /Gas Research	Stephens, et al., 1985

1981-82)	Washington Irrigation and Development Company (WIDCO) coal mine	Institute (now the Gas Technology Institute)/USDOE / Washington Power Company / Pacific Power & Light / Sandia National Laboratory and Radian Corporation	
1987/8	Rocky Mountain 1, 2, Carbon County, Wyoming, USA	US Dept of Energy	
Late 1980s – 2004 (Purdue 1980 – present)	China	SinoCoking Coal and Coke Chemical Industries, Inc. (www.scokchina.com), a Florida corporation, located in Pingdingshan, Henan Province, China. UCG centre at China Univ. of Mining and Technology, Beijing.	>15 trials have already occurred there. https://globenewswire.com/news-release/2015/06/16/744901/10138623/en/SinoCoking-Issues-Update-on-Syngas-Production-and-the-Company-s-Contribution-to-a-Greener-China.html http://www.coal-ucg.com/publishedarticleonucg.html
1994	Huntly West, Huntly Coal Basin, New Zealand	Solid Energy New Zealand Ltd With US technical assisitance Since 2005, with Ergo Exergy Technologies Inc http://www.ergoexergy.com/about_us_ourb_projects_solid.html	Pre feasibility studies undertaken during 2008 and 2009.
1997 BGS (1993-1998)	El Tremedal, Tereul Spain	A Spanish, UK, Belgian JV supported by EU using CRIP	Chosen on the grounds of its geological suitability, coal seam depth (550m- 700m) and the availability of extensive borehole data. http://www.osti.gov/scitech/biblio/34922

			0-el-tremedal-underground-coal-gasification-field-test-spain-first-trial-great-depth-high-pressure http://www.coal-ucg.com/currentdevelopments2.html
1999	GAIL, Rajasthan, India	Gail India in co-operation with the State Government and Ergo Exergy http://www.gail.nic.in/final_site/index.html http://www.ergoexergy.com/about_us_ourb_projects_gail.htm	Lignite seams at depths of between 230m and 900m.
1999-2013 *Purdue: 1990 – 2015?*	Hopeland, nr Chinchilla, Qld, Australia	Linc Energy (see report text here, Chap3. And QISP etc) But note also…. http://www.ergoexergy.com/about_us_ourb_projects_chinch.htm The Chinchilla site had been idle after April 2003. After operating the site and leading the project since its conception, Ergo Exergy terminated arrangements to provide εUCG™ technology to Australian company Linc Energy Ltd in September 2006 with the purpose of concentrating on other active commercial UCG projects worldwide.	Nine process wells, producing gas from a 10 metre-thick coal seam at a depth of 140m. Intermittent developmental work. http://www.coal-ucg.com/currentdevelopments2.html Walker et al (2001)
2007-2015	Majuba, UCG Project, Mpumalanga, South Africa	Eskom Holdings Ltd http://www.eskom.co.za/Pages/Landing.aspx http://www.ergoexergy.com/about_us_ourb_projects_eskom.htm	Permian age coals at c 280m depth

2007-date (intermittent)	Walanchabi City, China	ENN Group Co Ltd	One of >16, possibly 20 trials in China since 1990
2007	Stone Horne Ridge, Southern Alaska	Laurus Energy, Cook Inlet Region Inc. (CIRI), a Native American owned corporation in Alaska, and Ergo Exergy Technologies Inc http://www.ergoexergy.com/about_us_ourb_projects_ciri.html	?
2007/8	Thar project, Block III in the East of Sindh Province, Pakistan	Cougar Energy UK (47.8% owned by Cougar Energy Limited, Australia). http://www.ergoexergy.com/about_us_ourb_projects_cougaruk.html	Coal seams of varying thickness from 8m to 23m, at depths ranging from 115m to 205m.
2008-12	Bloodwood Creek, Dalby, Queensland, Australia	Carbon Energy	https://www.ehp.qld.gov.au/management/impact-assessment/eis-processes/bloodwood_creek_underground_coal_gasification_project.html Effective operation for 20 months. See Mallett (2015)
2008	Japan	Nine universities and research institutions, including Gunma University, Hokkaido University and the National Institute of Advanced Industrial Science, an d a consortium of 12 companies plan to build a test facility in a domestic mine.	The University of Tokyo has undertaken technical and economic studies of UCG, and maintains a watching brief on behalf of NEDO. Japanese coal companies are interested in the technology as a possible export opportunity.

2009 – 2011 (intermittent)	Swan Hills ISCG, Alberta, Canada	Swan Hills Synfuels (some development work for Clean Fuels in 2012-14)	1400m http://swanhills-synfuels.com/gas-manufacturing/demonstration-project/
2009	Mulpun Project in Chile – current status unclear.	Carbon Energy (An environment permit for process characterisation/design plan etc was prepared)	http://www.carbonenergy.com.au/irm/content/mulpun-project-chile.aspx?RID=223 Was a 2 m seam pre-feasibility study 103Mt of coal.
Post 2010-14	Parkland County, Alberta and Nova Scotia	Laurus Energy http://www.ergoexergy.com/about_us_ourb_projects_laurus.htm	Currently preparing several UCG power projects in Alberta and Nova Scotia.
2010/11 – 2014 (intermittent)	Kingaroy, Tarong Coal Basin, Queensland, Australia	Cougar Energy Ergo Exergy 's Technologies Inc. Under development since 2006, ignition of the underground gasifier at Kingaroy was initiated and first gas produced on 15 March 2010. http://www.ergoexergy.com/about_us_ourb_projects_cougar.html	The gasification process targets two seams ranging from 130m to 300m in depth and 2m to 17m in thickness.
2011-date (testing/intermittent)	Dobrudzha/Varna, Bulgaria	Overgas Inc Research&Demo project	EU-co-funded development with CCS modelling/testing
c.2011 - 2?	Mongolia	Hebei Xin'ao Group, Mongolia	100,000 tpa. Methanol http://www.bcgenergy.co.uk/ucg-explained/ucg-around-the-world
2007 project initiated in	Barbara, Mikołow, Poland.	"Barbara Project" *Largely technical focus until 2013. Now*	Central Mining Institute, Clean Coal Technology

1940s mine complex, 2009 field trial; 2+ years demonst-rator project 2011-14. New COGAR and TOPS EU projects 2013-16	Also Bobreck, Piast, Belchatow, Poland	*considering "safety and environmental aspects" No data yet available.* Reports of studies on tests and operations from 1960s to 2007. Papers 2011 Stanczyk, K; Dubinski, J etc.	Centre, Katowice University leadership and technical analyses. http://www.coalresearchforum.org/MES%202014,%20Kegworth,%2015-05-14,%20(pdf%20versions)/K%20Kapusta,%20CMI,%20Kegworth,%2015-05-14.pdf Also HUGE/HUGE2 EU funded programme on Hydrogen oriented UCG demonstrations. http://www.cleantechpoland.com/?page=news_old&id=39
2013?	Kaitha coal block, Ramgarh District, India	Abhijeet Group, India, AE Coal Technologies Ltd, Ergo Exergy http://www.ergoexergy.com/about_us_ourb_projects_ae.html	Feasibility

Other sites referred to in literature and marketing materials - Claromeco, Argentina; Ukraine – Donbass Coal field http://www.etf.com/sections/features-and-news/3161-underground-coal-gasification-an-old-energy-revolution-whose-time-has-come?nopaging=1 no real details; Kemerovo, Siberia. Also a range of modelling work, sometimes based on bores and seismic work in some locations – e.g. Ergo Exergy Montreal 1993. Chinese sites appear many but details are scant. See, for one example in Fenghuangshan, in 2012. http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-223X2012001000011

In 2014 it was also reported that Linc was planning a UCG operation in Tanzania.

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