Underground Coal Gasification in South Australia

Government of South Australia
Department of the Premier and Cabinet

8 KEY POINTS

1 There has been no Underground Coal Gasification (UCG) or In-situ Gasification (ISG) to date in South Australia.

2 UCG is regulated under the *Petroleum and Geothermal Energy Act 2000* (PGE Act), administered by the Department of the Premier and Cabinet – Energy Resources Division (DPC-ERD) in close consultation with co-regulatory agencies.

3 This existing regulatory framework for the upstream petroleum industry in South Australia continues to ensure the protection of natural, social and economic environments, including public health.

4 In order for a proponent to undertake UCG testing, in accordance with the PGE Act, an Environmental Impact Report (EIR) must be prepared in consultation with all potentially affected people, enterprises and organisations. In particular, the EIR must describe the reasonably foreseeable events that could pose a threat to the natural, social and economic environments. A Statement of Environmental Objectives (SEO) must then be prepared stating the objectives that must be achieved to address the impacts described in the EIR.

5 DPC-ERD regulates in close consultation and under existing administrative arrangements with the Department of Environment, Water and Natural Resources (DEWNR), the Environment Protection Authority (EPA), Primary Industries and Regions SA (PIRSA), SA Health and Safework SA.

6 The EIR and SEO will need to demonstrate how potential impacts are prevented through appropriate design, construction and modelling and importantly how this will be measured/monitored.

7 UCG will not be permitted in South Australia unless a proponent can demonstrate to DPC-ERD that:

- All risks that may adversely affect other users of the land can be reduced to as low as reasonably practicable (ALARP); and
- All concerns from potentially affected stakeholders (including land owners, enterprises, cultural heritage and native title groups, community groups and other government departments) have been adequately addressed under the consultation requirements of the PGE Act.

8 If an UCG project cannot demonstrate compliance with regulatory requirements, then approval for this project will not be granted. This holds true for all projects regulated under the PGE Act.

www.petroleum.dpc.sa.gov.au

FAQ frequently asked questions

What is Underground Coal Gasification or In-situ Gasification and how does it work?

UCG also referred to as ISG is a technique by which solid coal underground is converted in-situ (in position) into a gaseous product known as synthesis gas, or syngas. Syngas is composed mainly of carbon dioxide, hydrogen, carbon monoxide, methane, nitrogen, steam and gaseous hydrocarbons.

In the simplest UCG configuration, displayed below in Figure 1, two wells are drilled into a coal seam approximately 30 metres apart, one for what is referred to as the inlet well and the other as the outlet well. This dual well configuration is designed to create a direct linked system that facilitates retaining product-gas pathways in the seam and provides for tight spatial control.

An oxidant (a relative combination of air, pure oxygen and water) is then introduced through the inlet well, at the same time as an initiation device is used to start the UCG reactions in the coal seam. As the coal within the seam is consumed, a series of reactions convert the solid fuel into syngas, which is then extracted through the outlet well to surface for processing and/or destruction. As the UCG reactions proceed and coal is consumed, an underground chamber (void) forms and grows in size. This underground void is commonly referred to as the gasifier chamber. The gasification reactions within the gasifier chamber typically occur at temperatures of between 900°c and 1200°C, but may reach up to 1500°C.

The UCG process can be stopped at any time by shutting off the oxidant supply from the inlet well, which in effect starves the burn. An additional measure often used to supplement stopping the UCG process is through the injection of water which floods the chamber, thereby extinguishing the coal.

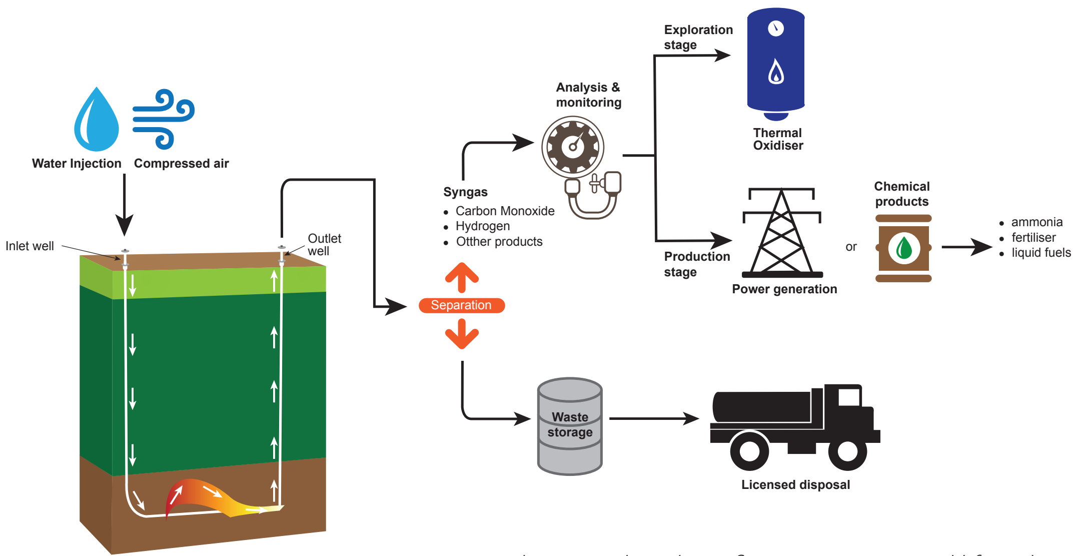

Figure 1 Underground coal gasification process and lifecycle

Why not use conventional mining methods?

The process of UCG enables the development of deep coal resources where open-cut or underground mining are identified as not feasible or as uneconomic.

What are the uses of syngas?

Syngas can be used for a variety of downstream applications, such as power generation, or as feedstock for recognised chemical products like methanol, ammonia, fertilizers, synthetic natural gas and liquid fuels.

What legislation is underground coal gasification in South Australia regulated under?

In South Australia, all oil and gas exploration and production activities are regulated under the PGE Act and associated Regulations. The PGE Act and its Regulations are publicly available on the South Australian legislation website.

All activities regulated under the PGE Act are also subject to the provisions of other state environmental regulation such as the *National Parks and Wildlife Act 1972*; the *Natural Resources Management Act 2004*; the *Work, Health and Safety Act 2012*; and the *Environment Protection Act 1993*. This in turn creates another layer of protection in addition to the best practice regulatory regime under the PGE Act.

The PGE Act forms the one window to government for industry whereby, through the statement of environmental objectives as a regulatory instrument under the PGE Act, the requirements of the other relevant pieces of legislation are incorporated into the DPC – ERD's approval and compliance monitoring processes.

South Australia's petroleum exploration, development, production, transport and processing in both the Cooper Basin (in the Far North) and the Otway Basin (in the South East) of the State have for decades been managed in ways that reduce risks to as low as reasonably practicable, without any significant impacts on social, natural and economic environments. This has established the environmentally sustainable development credentials of the upstream petroleum industry in the State.

What chemicals are produced in an underground coal gasification reaction?

Syngas is generally composed of a varying mixture of carbon dioxide, hydrogen, carbon monoxide, methane, nitrogen, steam and gaseous hydrocarbons. The particular percentage composition of syngas can vary quite widely between different UCG fields, from tests at the same site, and even between different test time periods.

Table 1 illustrates calculated average dry product gas composition for all air-blown and oxygen steam blown periods of US tests, which is indicative of potential syngas percentage compositions that may occur should UCG be undertaken in South Australia.

Table 1 *Average dry product gas composition (mol%) of almost all U.S field tests done on bituminous or sub-bituminous coal (Camp 2017)**

Species	Air Blown	Oxygen Steam
N_2+Ar	53.87%	2.30%
O2	0.20%	0.00%
H_2	13.49%	33.37%
C0	10.69%	9.82%
$C0_2$	15.99%	42.08%
C_2+HCS	0.45%	1.00%
NH_3+NO_x	0.60%	1.30%
S Oxides	0.20%	0.30%

**David W Camp. 2017. A Review of Underground Coal Gasification Research and Development in the United States. Lawrence Livermore National Laboratory, pp. 97-98.*

The role of DPC-ERD in administering the PGE Act and relevant regulations is to provide assurance to the community that the design and execution of regulated activities will achieve the approved objectives of the relevant SEO.

How is the risk of chamber collapse managed?

Mitigating the risk(s) of potential chamber collapse is expected to be explicitly addressed through the SEO. Provision/s which would be required within SEO's for avoiding chamber collapse, in accordance with the PGE Act, will need to address the certainty and adequacy of geotechnical assessment reports and ground disturbance modelling to ensure no gasifier induced subsidence is measured at the surface

Similarly to removing coal through underground conventional mining methods, underground coal gasification has the potential to cause the overburden above and surrounding the gasifier chamber to collapse, rubblize, fracture, and strain. These effects can result in varying levels of surface subsidence, and contribute to potential contamination events via opening fracture pathways.

While conventional mining industry practices have developed mitigation measures such as room-and-pillar or long wall mines, the nature of UCG means that there is a lesser degree of control over and knowledge of material removal geometry[1] . As such, best practice geotechnical modelling and engineering design is essential in assuring that UCG operation effects to the subsurface are reduced to ALARP and acceptable.

A key best practice mitigation measure in the prevention of largescale chamber issues and surface subsidence, is appropriate site selection. As such, UCG projects are typically planned and operated to avoid geo-mechanical structures which induce or facilitate geo-mechanical faulting or large-scale collapse. Any potential UCG SEO will be required to include appropriate and measurable assessment criteria that include the undertaking of detailed geological characterisation and careful geotechnical design to ensure that geo-mechanical settings and project designs are suitable and will allow for safe and efficient operation.

1 David W Camp. 2017. A Review of Underground Coal Gasification Research and Development in the United States. Lawrence Livermore National Laboratory, pp. 109-110.

How are potential health impacts addressed?

The objectives of the PGE Act and its Regulations are to ensure that all risks to the health and safety of the community and to the environment are either completely avoided, or managed and reduced to a level that is as low as reasonably practicable and acceptable to the community. Potential health impacts to both employees and the adjacent communities must be managed effectively and the SEO process seeks to adequately address such risks prior to any approval being granted.

Stakeholder concerns in relation to UCG generally include pollution of drinking water supplies and air pollution. Example provisions for addressing health and safety risk(s) in accordance with the PGE Act, in relation to UCG, include:

- Regular air quality measurements indicate levels are below relevant health-based air quality criteria (as listed in the Environment Protection (Air Quality) Policy) at sensitive receptors (i.e. towns or residences).
- Stakeholder complaints regarding air quality or odour are documented and reasonable steps taken to address them are demonstrated.
- Groundwater monitoring in accordance with the monitoring plan does not indicate a sustained change to background groundwater quality at monitoring wells located at the gasifier buffer zone boundary, as a result of demonstration plant activities.

How is groundwater protected from contamination?

The objectives of the PGE Act and its Regulations are to ensure that all risks to the health and safety of the community and to the environment are either completed avoided, or managed and reduced to a level that is as low as reasonably practicable and acceptable.

The mitigation of any potential risk(s) of groundwater contamination is expected to be explicitly addressed through the SEO. Example provisions which would be required in SEO's for protecting groundwater, in accordance with the PGE Act, will need to address the certainty of containment and/or removal of chemicals of potential concern (COPC) to prevent and/or minimise groundwater contamination.

As a part of the UCG process, COPC are continually generated, destroyed, and removed, leaving only small amounts confined locally. A key risk of UCG is process gas containing COPC will escape when there are outward pressure gradients and a permeable path for gas flow. As illustrated in Figure 2 below, there exists multiple possible contaminant transport pathways and opportunities in the geo-mechanics of a site, which need to be identified and monitored.

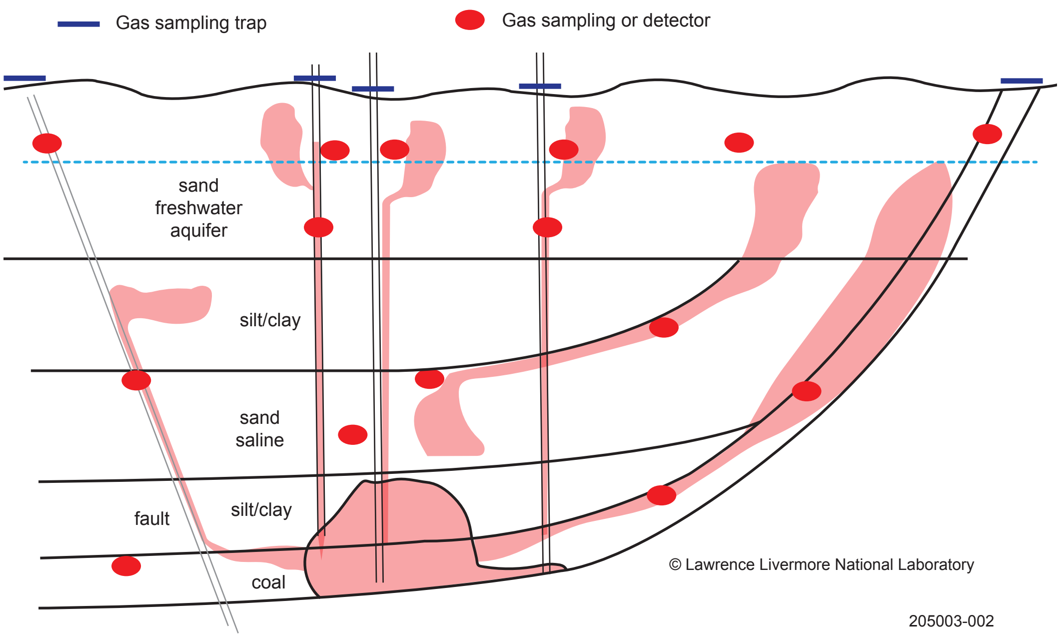

Figure 2 *Possible UCG contamination transport pathways and opportunities for using gas detection or sampling to discover them early (Camp and White, 2015).*

How is groundwater protected from contamination?

Containing these COPC within the gasifier chamber and its closer confinement zone will be essential to ensure groundwater and surround lands are not contaminated. A SEO will need to establish clear and measurable environmental objectives and assessment criteria that establish adequate pressures in the gasifier so that the gradients driving the flow are inward, and contamination events do not occur.

A key aspect of ensuring containment and preventing the escape of COPC will be appropriate site selection, with suitable (low) permeability barriers. Other best practice mitigation measures include appropriate well design and integrity management, gas detection and sampling for early far-field detection of escaping gas.

Site selection is often identified as the key aspect of ensuring containment because the permeability of a particular field or site selected strongly affects the potential for the amount of gas escape and contamination transport pathways to protected groundwater.

Preferential sites for UCG, according to Camp and White (2015), are those with favourable characteristics relating to groundwater protection which include but are not limited to adequate depth below aquifers, thick and impermeable overlying strata, absence of vertical connectivity, low dip angle (5 to 25 degrees), and mechanically competent overlying rock and few faults[1] . Should it occur, these characteristics result in geo-mechanics that will tend to leave less more narrowly localised contamination, have lower probabilities of further contamination transport, and produce less impact to people, agriculture, and valuable groundwater resources if there are problems[2] .

1 David W Camp & Joshua A White. 2015. Underground Coal Gasification: An Overview of Groundwater Contamination Hazards and Mitigation Strategies. Lawrence Livermore National Laboratory.

2 Ibid

Site selection and preferential site characteristics suited for UCG operations is further highlighted by the Independent Scientific Panels (ISP) review of underground coal gasification pilot trials in Queensland. The ISP outlined as a general guide, a UCG site should operate under a rigorous risk-based approach and include, at least the following attributes, as per Table 2.

Table 2 Independent Scientific Panels recommended site attributes for Underground Coal gasification (Moran et al. 2013).

Recommended site attributes for Underground Coal Gasification
Coal seam at sufficient depth to ensure that any potential environmental contamination can be demonstrated to have minimal environmental consequences. With deeper coal, there are fewer useable aquifers and, if appropriate sealing horizons are present above the gasification depth there is much lower probability of materials (gas or liquids) moving to the surface.
Coal seam sufficiently thick to sustain gasification with reasonable likelihood of economic viability
Rank of coal should be lignite to non-swelling bituminous coal
Hydraulic head sufficient to contain efficient gasification
Cal seam capped by impermeable rock
Target coal located so that there is sufficient thickness between the target coal seam/measure and any valuable aquifer higher up the geological succession
Sufficiently distant from rivers, lakes, springs and seeps to avoid contamination should chemical escape the cavity
Absence of faulting or intrusions in the vicinity of the site. This is dependent on the size of the cavity
Sufficient distance from the nearest town and/or intensive surface infrastructure e.g. irrigation or feedlots, and areas of significant environmental value, e.g. world heritage forests or wetlands, to avoid contamination should chemicals escape the cavity and to minimise impacts of odours.

Camp and White (2015) have also developed a Hazard screening checklist that provides additional analysis for characterisation of suitability for UCG activity, which is available via http://petroleum.statedevelopment.sa.gov.au/__data/assets/pdf_file/0006/299679/llnl-ucg-groundwater-report-2015a.pdf.

Additionally, other key mitigation measures and best practice operations, which reduce the risk of unacceptable groundwater contamination, in line with the Clean Cavern concept and Camp and White's (2015) recommendations include :

- Choose a site that minimises the exposure to sensitive environmental receptors. This means minimising:
  - Nearby, down gradient, and up-dip uses of groundwater and surface water
  - Proximity to potentially –usable aquifers
  - Proximity to residences, businesses and recreational activities of people, and valued animal habitats
- Choose a site that has barriers to transport of contaminants from the immediate and contaminated UCG process area to sensitive environmental receptors, and do not create or increase transport pathways
- Assure no leaks of process gas from instrument or process wells into shallower strata
- Assure during operation that the pressure in all gas volumes that are connected to the cavity is lower than the water pressure in the surrounding at all adjacent elevations (i.e. at the elevation of the highest gas-connected fractures).
- Minimise the quantity of contaminants left underground in and near the cavity and exit product pathways.
- Characterise groundwater and pore gas in the immediate process area and the surroundings, especially in or near aquifers and sensitive receptors before operations begin, during and afterwards for several years.

Where a project cannot demonstrate that it can be undertaken in a manner which will comply with regulatory requirements, that is to be environmentally sustainable, then approval will not be granted.

Acronyms

Departmental names

DPC-ERD	Department of the Premier and Cabinet Energy Resources Division
DEWNR	Department of Environment, Water and Natural Resources
EPA	Environment Protection Authority
PIRSA	Primary Industries and Regions SA

Acts

PGE Act	Petroleum and Geothermal Energy Act 2000

General

UCG	underground coal gasification
ISG	in-situ Gasification
EIR	environmental impact report
SEO	statement of environmental objectives
ALARP	as low as reasonably practicable
COPC	chemicals of potential concern
ISP	Independent Scientific Committee

Further Information

Should you have any further questions or concerns please contact:

Mr Michael Malavazos
Director Engineering Operations,
Energy Resources Division,
Department of the Premier and Cabinet
Phone 8463 3245; or
email: **michael.malavazos@sa.gov.au.**

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12/01/2018-205003