UNDERGROUND COAL GASIFICATION

BURNING **COAL SEAMS** UNDERGROUND AND EXTRACTING THE RESULTING GAS TO USE AS FUEL.

VERY HIGH **WATER CONSUMPTION**, CATASTROPHIC GROUNDWATER CONTAMINATION, AND DRAMATICALLY INCREASES ACCESSIBLE COAL RESOURCES WITH SEVERE IMPLICATIONS FOR CLIMATE CHANGE.

WHAT IS IT?

Underground Coal Gasification (UCG) is a way of producing fuel from coal seams, generally those that are uneconomical to extract using conventional mining methods because they are too thin, too deep or too low-quality. Pairs of wells are drilled into the coal seam. One well is used to ignite the seam and control the flow of air, oxygen or steam, allowing the coal to be partially burned. The other well is used to extract the resulting gases which can then be separated at the surface into carbon dioxide, water, and syngas (see below). Prior to ignition, hydraulic fracturing (fracking), directional drilling, or various other techniques are used to connect the wells together and allow the gas to flow.

The syngas (an abbreviation of synthesis gas) is made up of hydrogen, methane, carbon monoxide, and can be directly burned to generate electricity, or used to make other fuels and chemicals such as hydrogen, ammonia and methanol. The process is chemically similar to how town gas (also known as coal gas) used to be made from coal before the adoption of natural gas in the mid 20th century.

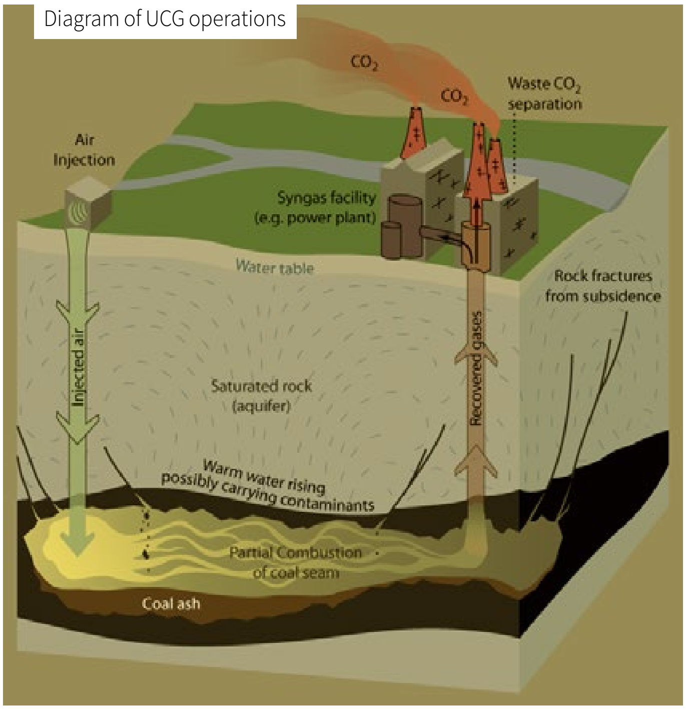
Experiences with town gas should as serve as a warning. The industry left a legacy of highly contaminated industrial sites around the world. The UCG process results in similar pollutants, the main difference being that UCG takes place in the open environment instead of a sealed metal chamber, increasing the risk of contamination.

The idea of UCG has been around for a long time, and experiments have been carried out since the 1912 in the UK,[1] with further experiments in the 1930s. The use of the technology peaked in the 1960s in the Soviet Union, with up to 14 industrial-scale UCG fired power plants operating at different times between the 1950s and 1960s. Except for the Angren plant still operating in Uzbekistan, all the USSR's plants were closed down by the end of the 1960s, following significant natural gas discoveries. Initially projects exploited shallow, easily accessible coal seams, but recent technology such as directional drilling, means that deeper and harder to reach seams can now also be accessed.

Recent pilot projects have been carried out in Australia, China, New Zealand, South Africa, New Zealand, Canada and the US, and one commercial plant has been operating in Uzbekistan (Angren) for over 40 years.[2] A host of other countries are developing projects including the UK, Hungary, Pakistan, Poland, Bulgaria, Chile, China, Indonesia, India, and Botswana. Most UCG projects aim to produce electricity at the same site where extraction and gasification takes place. There are also plans to create liquid fuels from syngas using the Fischer-Tropsch process (so-called 'coal to liquid' technology – see separate factsheet).

Test projects have been plagued by accidents, and have resulted in massive long term groundwater pollution. The implications for climate change are disastrous, as the technology produces large greenhouse gas emissions and would give access to vast previously inaccessible coal resources.

Diagram of UCG operations



CLIMATE CHANGE

Whether in coal power stations or using UCG, burning coal produces more greenhouse gas emissions (GHG) than almost any other fossil fuel. UCG is particularly inefficient as energy is wasted heating the rock surrounding the chamber where the gasification takes place (known as the gasifier or combustion chamber). Other processes, such as removing hydrogen sulphide from exhaust gasses also require large amounts of energy. Altogether around 40% of the energy from burning the coal is lost in the process.[3]

This wasted energy, combined with the high CO_2 content and relatively low energy content of the syngas, mean that UCG produces large greenhouse gas emissions. Reliable figures are difficult to find, but it has been estimated that UCG would have CO_2 emissions comparable with that from a conventional coal power station.[4]

Damage from coal seam fire in Glenwood springs, U.S.

"UCG PROJECTS AROUND THE WORLD HAVE BEEN PLAGUED WITH ACCIDENTS, INCLUDING EXAMPLES OF CATASTROPHIC GROUNDWATER CONTAMINATION"

Another issue is the amount of coal that UCG would allow to be accessed. Global coal resource figures vary significantly, but it has been estimated that there are still around 860 billion tonnes of coal remaining that can be accessed with conventional mining techniques,[5] possibly enough to last over a hundred years. However, using UCG technologies, coal seams that are uneconomical to mine can be exploited, giving access to even more coal, conservatively estimated as an extra 600 billion tonnes.[6] The real figure could be much higher, as the total global coal resources (which includes coal that cannot be accessed with current technology) have been estimated to be in the trillions of tonnes.[7]

If we are to reduce carbon emissions to anything like the levels required to maintain a reasonably habitable planet we must move away from all forms of fossil fuel as fast as possible. Measuring from the start of the industrial revolution (around 1750), a maximum of 500 Gigatonnes of carbon (GtC) can be emitted to the atmosphere while still avoiding most serious impacts and the risk of irreversible and uncontrollable changes to the climate.[8] *Between 1750 and now (2014), we have already emitted about 370 GtC leaving a limit of 130 GtC that could be further added.*[9]

In order to stay within this limit we have to leave the vast majority of the remaining conventional oil, coal and gas in the ground. Estimates vary significantly, but remaining conventional coal reserves alone are well over 500 GtC.[10]

Clearly developing UCG and giving access to enormous further coal resources, is absolutely incompatible with staying below this limit.

Carbon Capture and Storage (CCS)

Proponents of UCG say that the technology is ideally suited for combination with CCS as it is relatively easy to remove the concentrated CO_2 and inject it back into the exhausted coal seam. The argument then goes that CO_2 could be removed directly from the UCG gas, or from the flue gas after combustion. However, there are significant concerns over the viability of CCS and UCG technologies, and there are no demonstrated projects where they work in combination.

Despite industry claims that exhausted gasifiers would be ideal storage sites for CO_2 produced during the process, there are in fact a number of serious problems that make them unsuitable. The expected collapse of the rock layer above gasifier means that the integrity of any potential 'cap rock' is likely to have been compromised, allowing CO_2 to escape. High pressures and temperatures during and after gasification may also cause fracturing and changes in the permeability of the rock surrounding the gasifier, creating pathways through which CO_2 could escape.[11] There is also no guarantee that there is any 'cap rock' present above the coal-seam since, unlike oil and gas, coal seams don't need impermeable rock above them to hold the coal in place.

Due to high underground pressures, UCG carried out on deep coal seams would mean that the CO_2 would have to be stored in a 'supercritical' fluid state (a state in which the CO_2 has the density of a liquid but flows like a gas). If this supercritical fluid escapes to shallower depths where pressures are lower, the CO_2 would turn into gas, leading it to rapidly expand and become much more mobile. This could result in a sudden release of CO_2 gas to aquifers or even to the surface. CO_2 stored in the seam is also likely to react with pollutants and make them more mobile. It can also react with water and ash to make carbonic and sulphuric acid which can leach further contaminants from the rock, and reduce the sites' ability to store CO_2.[12] Due to these and other factors, investigations into UCG have concluded that "it is considered unlikely therefore, that sequestration in an exhausted gasifier could provide a secure long term repository of CO_2"[13] and that there "remains substantial scientific uncertainty in the environmental risks and fate of CO_2 stored this way".[14] CO_2 storage in adjacent coal seams is also being considered, however this would only be possible in the highest permeability seams.

There are also numerous critical problems with CCS itself, which remains a largely unproven technology, especially at the enormous scale that would be required (see CCS factsheet).

Proponents of unconventional fossil fuels often argue that with CCS technologies, these new energy sources could be exploited at the same time as reducing GHG emissions. However, even if the huge problems with CCS technology are overcome (and this currently looking extremely unlikely), it would not change the fact that we need to move away from all forms of fossil fuel, conventional and unconventional, as soon as possible.

In the most optimistic (and highly implausible) scenario, CCS could be used to reduce a small proportion of emissions from fossil fuels. In reality, the promise of CCS being implemented in the future is being used to allow the continued expansion of fossil fuel production, to prevent alternatives from being developed, and to deflect attention away from approaches which tackle the underlying systemic causes of climate change and other ecological crises. Ultimately CCS is a smokescreen, allowing the fossil fuel industry to continue profiting from the destruction of the environment. (see 'Carbon Capture Storage' factsheet for more information).

OTHER SOCIAL AND ENVIRONMENTAL ISSUES

Groundwater pollution

The various UCG projects that have been carried out around the world have been plagued with accidents, including examples of catastrophic groundwater contamination.[15] Studies in the Soviet Union in the 1960s revealed that UCG could result in widespread groundwater contamination.[16]

In the 1970s a project at Hoe Creek, Wyoming, USA resulted in massive groundwater contamination.[17] Potable groundwater was polluted with benzene, requiring an expensive long-term clean up operation.[18] In 2011, Brisbane based company Cougar Energy was ordered to shut down its trial underground coal gasification project at Kingaroy due to environmental concerns over benzene contamination.[19]

The gasification cavity is a source of both gas and liquid pollutants that risk contaminating nearby groundwater. These include mercury, arsenic and selenium,[20] coal tars containing phenols, BTEX (benzene, toluene, ethyl benzene, xylene) and other volatile organic compounds, and polycyclic aromatic hydrocarbons (PAHs).[21] [22] Of particular concern are benzene and phenols, as they are water soluble, can be transported by other chemicals, and are more likely to float upwards due to their low molecular weight. Altogether, one hundred and thirty-five compounds that might pollute the local groundwater sources near UCG sites have been identified.[23]

There have been instances of contaminants being forced out into groundwater due to high pressures in the gasifier. The industry claims that by maintaining pressures lower than those in the surrounding grounwater they can eliminate the risk of contamination, as water will flow towards the gasifier rather than away from it. However, in practice controlling the pressures has proven difficult, and operating at lower pressures can result in less efficiency and more contamination.[24] The Chinchilla test site in Australia claimed to have prevented contamination by controlling pressures, however others described it as "rather unsuccessful".[25] In addition, during previous test projects gasses escaped from the gasifier, finding the paths of least resistance, and carrying liquid pollutants along with them against the direction of groundwater flow.[26] Any large open fissures or faults, the presence of which could be impossible to predict, would create emission pathways that could not be controlled by changing the pressures. Coal seams typically contain many natural fractures.

Damage from an underground coal fire in Centralia, U.S.

In many demonstration projects in shallow seams the area above the combustion chamber collapsed, and it is assumed at deeper sites that this will always happen. This can cause surface subsidence (see below), but also creates fractured pathways around the collapsed chamber for contaminants to leak into the groundwater. There is also the possibility of so called 'cross contamination' where already poor quality groundwater around the coal seam can flow to good quality ground water areas due to the changes in rock structures and water pressures caused by the UCG process. Another issue is the fact that the heat generated by gasification causes groundwater above the gasifier to rise, carrying contaminants with it.

The contaminated ash left in the exhausted coal seam will remain there more or less indefinitely, meaning that it is a potential source of groundwater contamination decades or even centuries after gasification. Due to the depth of the coal seams where most UCG would be likely to take place it would also be extremely difficult to deal with any water contamination problems.

Water consumption, waste and surface water

Several aspects of the UCG process (such as initial mining, operation, then flushing and venting once gasification has finished) require injecting and extracting water from the gasifier. This means that the process consumes large volumes of water and produces large volumes of contaminated water. Waste water will vary significantly in terms of the contaminants present, as different coal seams and different stages of the process will generate different pollutants. This makes treating the waste water particularly difficult.

There is also the risk of surface spillage from waste water storage facilities and transportation, and pollutants being released to the environment due to accidents at the site. In Australia, Carbon Energy was charged in 2011 with not reporting a series of "very serious" incidents involving spills and disposal of waste water.[27]

Syngas and air pollution

The burning of UCG syngas at the surface to produce electricity is known to generate air pollution, including oxides of sulphur and nitrogen, hydrogen sulphide, particulates and heavy metals such as mercury and arsenic.[28] The syngas also contains contaminants which create problems for processing and transportation. These contaminants include dust, soot and tars which can clog up pipes and equipment; oxygen, from air or poor combustion control, which can potentially result in explosive mixtures; chlorine and chlorine compounds which can corrode equipment.[29]

Subsidence

As the reaction burns through the coal seam in the gasification chamber, it leaves a hole behind it filled with ash. The roof area directly above this hole usually collapses, which can result in subsidence at the surface, potentially damaging roads and buildings. The risk and extent of surface subsidence is greater the shallower the exploited coal-seam is, the larger the dimensions of the combustion chamber are and the weaker the rock is above the coal-seam. Underground and resulting surface subsidence can also affect the drainage patterns of surface water, the movement of ground water, with the potential to increase contamination, and can damage UCG injection and production wells.

A burning coal seam

Explosions and accidents

The high temperature and pressure flammable gases created by UCG, along with the blockages which can result from tar and soot contaminants mean there is the potential for explosions. This happened at the European UCG trial in Thulin, Belgium (1979-87), intended to test the feasibility of UCG on deeper coal seams. The trial had to be halted after one of the supply tubes to the burner became blocked leading to an underground explosion which damaged the injection well.[30] In 1984, another test project in France was stopped due to tar and particles blocking the production well.[31]

During tests in the 1990s in Spain, an attempt to restart a UCG operation caused the accumulation of methane underground resulting in an explosion which damaged the production well.[32] The injection and production wells are also prone to being damaged, as the gasification process results in extreme temperatures and pressures, and creates (as discussed above) cavities that are likely to collapse and compromise the integrity of the wells.

Scale

UCG plants produce a relatively small amount of power. The European trial in Tremedal, Spain in the 1990s only sustained gasification for a few days at a time, and briefly peaked to produce gas with the equivalent of 8 Mega Watts (MW)of power.[33] Eskom's trial project in South Africa has a similar output of about 9 MW.[34] A small coal fired power station produces well over a hundred times this much power and gets through as much coal in a day as many of the test projects burned in a year. Taking into account the energy lost from producing and burning the syngas, this means hundreds, possible even thousands of UCG plants could be required in order to replace just one coal power station. Considering the greenhouse gas emissions and the impact on groundwater resources experienced in test projects, scaling up UCG technology to provide a significant proportion of our energy would have a devastating impact on local environments and the global climate.

Industrialisation of countryside

UCG sites also require industrial equipment at the surface including drilling rigs, wellheads, connecting pipework, and plants for handling and processing the injection and production gases. As operations continue, additional wells and pipelines will be required, progressing further away from surface plants to access new coal supplies. There will also be a substantial increase in traffic volumes, in order to transport equipment and waste.

Damage from an underground coal fire in Centralia, U.S.

Uncontrolled burns

Coal seams sometimes start burning naturally as a result of lightning, forest fires or spontaneous combustion following exposure to oxygen in air. These fires can continue to burn for decades or even centuries. When close to the surface, oxygen from the atmosphere fuels the fire, with subsidence from the burning seam often providing more air as the burn continues. In uncontrolled burns at greater depths, such as old deep coal mines, the oxygen usually comes from ventilation shafts. Coal seam fires can have serious consequences. For example, in Centralia, Pennsylvania, US an uncontrolled mine fire beneath the borough that has been burning since 1962 has resulted in the population dwindling from over 1,000 residents in 1981 to 10 in 2010.[35]

Even with UCG of deeper coal seams there is a risk of uncontrolled burns as forgotten mine shafts, boreholes, damaged wells or geological faults could provide a source of air

WHERE, HOW MUCH AND WHO?

In recent years there has been renewed interest in UCG. There are about 30 projects using underground coal gasification in various phases of preparation in China and the Indian government has plans to use UCG to access the country's huge remaining coal reserves.[36]

South African companies Sasol and Eskom both have UCG pilot facilities that have been operating for some time. In Australia, Linc Energy has the Chinchilla site, which first started operating in 2000. Demonstration projects and studies are also currently under way in the USA, Western and Eastern Europe, Japan, Indonesia, Vietnam, India, Australia and China.[37] The Chukotka autonomous district in Russia's Far East looks set to be the first place in the country to implement the technology,[38] and Eon has signed a memorandum of understanding with the Hungarian government to develop UCG projects.

In the UK Cluff Natural Resources have plans to implement the first UK UCG site in Warwickshire. Another UK company, Clean Coal Ltd, had planned to carry out the first UK test project under Swansea Bay in Wales.

Other notable companies around the world involved in the development of UCG include: Swan Hills Synfuels in Alberta, Virginia, USA, Santos in New South Wales, Australian and Carbon Energy and Portman Energy which have developed UCG techniques.

In addition, the Underground Coal Gasification Association,[39] an industry membership organisation, has been playing a key role in promoting the technology.

For more information on resistance see the Corporate Watch website (corporatewatch.org/uff/resistance)

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