IEA CLEAN COAL CENTRE profiles

No 18–April 2015

Climate implications of coal-to-gas substitution in power generation

In 2014, with a 36% share of global power production, coal was the most widely used primary energy source in the power generating industry. Switching from coal to gas has been considered one of the principal methods of reducing greenhouse gas (GHG) emissions from the energy sector. Several recent studies question the implications for climate change of substituting coal with gas, especially in electricity generation.

Methane is an important GHG, as it is ~25 times more potent than CO_2 (over 100 years). Each GHG has active radiative or heat-trapping properties. To compare GHGs, they are indexed according to their Global Warming Potential (GWP), which is the ability of a greenhouse gas to trap heat in the atmosphere relative to an equal amount of CO_2. CO_2 assumes the value one (1). Though the most prevalent, CO_2 is the least powerful GHG. Nowadays the other GHG potencies or GWP are often expressed in million metric tonnes of CO_2 equivalents ($MtCO_2$-e). Despite its potency, as the amount of methane emitted due to combustion is a fraction of the CO_2 emitted and, as methane also has a shorter residence time in the atmosphere, which is approximately 10 years, its impacts were considered to be less detrimental compared to CO_2. Today, this is not the perception any more, and there is a plethora of material disputing that.

There are four main categories of unconventional natural gas: shale gas, coalbed methane (CBM), gas from tight sandstones (tight gas) and the least well-known methane hydrates. The report discusses mainly CBM and shale gas in detail. CBM refers to methane that is trapped within pores and fractures in underground coal deposits. Due to high underground pressures, the gas is usually found in a semi-liquid state, lining the inside surfaces of the coal matrix. CBM is chemically similar to conventional natural gas. CBM occurs, in conjunction with (hard) coal, at depths between 700 and 2000 metres. Extraction of CBM is through wells drilled directly into the coal seams. This became possible on a commercial scale relatively recently, especially since the 1990s, due to advances in drilling technology. Methane emissions occur at several stages during the production, supply and use of CBM. Methane recovered from working or abandoned mines is usually referred to as coalmine methane (CMM). Traditionally, methane was extracted from coals to reduce mining hazards, and the gas was generally vented to the atmosphere with large fans in the mines. Today, CMM is used for energy production. There are currently 355 coalmine projects in operation or under development. Total emissions avoided were calculated as 73.6 $MtCO_2$-eq.

Shale gas occurs at depths of ~1000 to 5000 metres. There are nearly 700 known shales worldwide in more than 150 basins. In 2013, only a few dozen of these shales had undergone proper assessment for production potentials, most of these are in North America. The potential volumes of shale gas are large and this is likely to reshape significantly the gas markets worldwide. The USA is the most active country in shale gas production, which almost doubled from 11 per cent of overall US gas production in 2008 to more than 20 per cent in 2010. This has more than doubled again between 2010 and 2013. Some consider that it may approach 50 percent by 2035.

There is considerable uncertainty over the amounts of methane emitted over the lifetime of a natural gas well. It is accepted that, in general, emissions from natural gas production are substantial and occur at every stage of the natural gas life cycle, from pre-production through production, processing, transmission and distribution. The US Environmental Protection Agency (EPA) estimates that more than 6 Mt of methane leaked from natural gas systems in 2011 in the USA. Measured as CO_2 equivalent over a 100-year timeframe, that is, more GHG emissions than those emitted by all US iron and steel, cement, and aluminium manufacturing facilities combined. The US EPA used emission factors from the 1996 Intergovernmental Panel on Climate Change (IPCC) study to estimate the contribution of natural gas systems to the US GHG inventory. Increasing evidence over the previous 16 years indicated that these emission factors were probably too low. In April 2011, the US EPA released updated factors. The US EPA has since released further updates, the latest on 4 April 2014. Many scientists and researchers consider these still under estimated.

IEA Clean Coal Centre is a collaborative project of member countries of the International Energy Agency (IEA) to provide information about and analysis of coal technology, supply and use. IEA Clean Coal Centre has contracting parties and sponsors from: Australia, Austria, China, the European Commission, Germany, India, Italy, Japan, New Zealand, Poland, Russia, South Africa, Thailand, the UK and the USA.

Each issue of **Profiles** is based on a detailed study undertaken by IEA Clean Coal Centre, the full report of which is available separately. This particular issue of Profiles is based on the report:

Climate implications of coal-to-gas substitution in power generation

Herminé Nalbandian

CCC/248, ISBN 978-92-9029-570-9, 92 pp, April 2015

This report is free to organisations in member countries, £100 to organisations in non-member countries for six months after publication, and free thereafter.

It has been reported that shale gas has a GHG footprint of 8–11% higher than conventional gas, where methane emissions from the upstream portion of the natural gas production are unmitigated. If correct, this underlines the importance of implementing existing control technologies and best practices that can minimise methane emissions and therefore reduce the methane footprint of the natural gas system. A clearer picture is expected to emerge when data from ongoing studies are analysed in conjunction with industry data reported to the US EPA GHGs reporting program. However, with hundreds of thousands of existing natural gas wells, thousands of miles of pipeline, and a growing interest in natural gas development throughout the world, a situation has to be considered where a complete picture of the amount of methane being emitted through natural gas systems may not be possible to obtain.

While there are similarities between shale gas and CBM and the methods used to extract them, there are important distinctions. In particular, shale deposits are usually less porous than coal and are often located deeper underground. As a result, shale gas can be more difficult to extract.

CO_2, methane and nitrous oxide are produced during coal combustion. Nearly 99% of the fuel carbon in coal is converted to CO_2 during the combustion process. The greater the efficiency of the combustion process, the less coal is consumed and therefore total emissions to the atmosphere are reduced including those of GHGs. The contribution of stationary coal combustion to total methane emissions is generally considered minor.

The life-cycle emissions for natural gas are reported as ~35% lower than coal on a heat-content basis. In terms of electricity production, natural gas had about 50–60% lower GHG emissions than those of a coal-fired plant. A current state-of-the-art coal-fired plant operating with a high efficiency ultra-supercritical steam cycle will be more efficient, more reliable, and have a longer life expectancy than its older subcritical counterpart, which achieves, in general, an average efficiency in the mid-thirties. Most significantly, an ultra-supercritical plant would emit almost 20% less CO_2 compared to a subcritical unit operating under similar duty. The developments in advanced ultra-supercritical steam cycles promise to continue this trend. A plant operating at 48% efficiency would emit up to 28% less CO_2 than a subcritical plant, and up to 10% less than a corresponding ultra-supercritical plant. Ultra-supercritical plants have been constructed and operated in Europe, Japan and the USA and more recently, in China.

The USA is currently 'the' country where there is a major programme of substituting coal-fired plants with gas-fired facilities. This is mainly due to the increase in natural gas production and the subsequent reduction in gas prices. At the end of 2012, there were 1308 coal-fired electric generating units accounting for 310 GW of electricity in the USA. In 2014, projections indicate that a total capacity of 60 GW will be retired by 2020, with 90% of the retirements occurring by 2016.

China has the world's largest coal-based power generation capacity. In 2014, natural gas played a small role in overall power generation. However, the government plans to invest in more gas-fired power generating capacity. Overall, China's effort to shift coal-fired generation to more gas-fired generation in the long term depends on the country's ability to increase domestic production through coal-to-gas conversion, shale gas and offshore reserves as well as imported sources.

Data indicate that, the ongoing shift from coal to gas in power generation in the USA is unlikely to provide the 50% reduction in GHG emissions typically attributed to it, over the next three to four decades, unless, gas leakage is maintained at the lowest estimated rates of 1-1.5% and the coal replacement rate is maintained at >5% per year. Although the coal replacement programme may be achievable, according to the many scientists and researchers reviewed in the publication, the 1-1.5% estimates contain significant uncertainty, and lack sufficient, actual, real-time measurements to guide policy decision-making at national level. Numerous studies conclude that if methane emissions exceed 3% of total gas production, the climate advantage of natural gas firing over coal disappears over the 20-year time horizon. Ultimately, switching fuels does not solve the GHG emissions challenge. Carbon capture and storage (CCS) will be necessary to mitigate the climate implications of GHG emissions if both fuels, coal and gas, continue to be used in power generation.

IEA Clean Coal Centre 14 Northfields London SW18 1DD
www.iea-coal.org | +44 (0)20 8877 6280 | email: mail@iea-coal.org