Assessing the feasibility of the "all-in-one" concept in the UK North Sea: offsetting carbon capture and storage costs with methane and geothermal energy production through reuse of a hydrocarbon field

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In order to limit anthropogenic warming to 2 °C above pre-industrial levels as per the Paris agreement, carbon capture and storage (CCS) must become a widespread industry by the middle of the century (Azar, Johansson and Mattsson, 2013; Scott *et al.*, 2013; IEA, 2014; IPCC, 2014). However, the initial capital costs of CCS are currently obstructing its development. Offsetting costs through enhanced oil recovery has had some success globally (IEA, 2015) and recent research suggests that the co-production of methane and geothermal energy could also prove financially viable (Bryant and Pope, 2015; Ganjdanesh and Hosseini, 2016). This system produces brine from with methane and geothermal energy are extracted and sold before dissolving captured CO_2 in the brine and reinjecting it into the subsurface where it sinks due to its relatively higher density, providing secure storage.

Here we build on this previous work and investigate an "all-in-one" system with onsite energy production and carbon capture and use Monte Carlo analysis to establish the energy balance of such a system using a depleted hydrocarbon field in the Inner Moray Firth of Scotland. The site was chosen to determine if this system would be viable in an area without the ideal deep, hot, geopressured aquifers proposed in (Bryant and Pope, 2015; Ganjdanesh and Hosseini, 2016) by reusing existing oil & gas infrastructure.

A combination of production data, well logs, end of well reports, and solubility data was investigated to produce a set of different scenarios. Firstly, the potential methane saturation was established by comparing theoretical saturation curves with evidence from oil & gas data. This allowed a calculation of the potential volumes of methane that could be extracted and sold. The second scenario considered using the methane to produce electricity onsite and exporting it to be sold into the UK national grid. The third scenario was for carbon storage only, and calculated the storage potential for the selected site. Finally, a full energy balance was calculated including brine production, electricity production, carbon capture, and carbon injection.

In the methane production scenario we find that when production costs are taken into account, the sale value of methane per m^3 brine is negative, with losses ranging between 2.7 and 1.3 $£_{2017}$. Similar results were found for the electricity production scenario with losses between 2.1 and 0.3 $£_{2017}$. However, when geothermal energy is taken into account alongside carbon capture and storage with produced electricity also used to run the system, the energy balance is positive in almost all cases with the minimum negative at 0.3 and the first quantile positive at 1.6 $£_{2017}$. The production costs used for these calculations were for oil production and so brine production figures are likely to be much lower.

The carbon storage potential for the depleted oilfield was between 18 and 26 million tonnes which would be enough space to store the CO_2 captured from a 500 MW power plant for around 20 years, assuming around 1 million tonnes captured per year. The amount of CO_2 produced by the "all-in-one" system requires less than 10% of the available 'space' in each m^3 of brine which opens up the system to outside sources of CO_2 for disposal for which it could charge.

An "all-in-one" system reusing existing oil & gas infrastructure is highly likely to have a positive overall energy balance with extra space available for disposal of outside sources of

CO_2. This re-use of infrastructure and positive energy balance suggest that such a system could overcome the financial barriers to development of a carbon storage industry in the North Sea and would be more cost effective than current plans for decommissioning.

References

Azar, C., Johansson, D. J. A. and Mattsson, N. (2013) 'Meeting global temperature targets - The role of bioenergy with carbon capture and storage', *Environmental Research Letters*, 8(3). doi: 10.1088/1748-9326/8/3/034004.

Bryant, S. L. and Pope, G. A. (2015) 'Storing carbon dioxide and producing methane and geothermal energy from deep saline aquifers'.

Ganjdanesh, R. and Hosseini, S. A. (2016) 'Potential assessment of methane and heat production from geopressured–geothermal aquifers', *Geothermal Energy*. Springer Berlin Heidelberg, 4(1), p. 16. doi: 10.1186/s40517-016-0058-4.

IEA (2014) *World Energy Outlook, 2014*, *International Energy Agency*.

IEA (2015) 'Storing CO2 through enhanced oil recovery', *International Energy Agency, Paris, France*.

IPCC (2014) *Fifth Assessment Report (AR5)*, *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. doi: 10.1017/CBO9781107415324.

Scott, V. *et al.* (2013) 'Last chance for carbon capture and storage', *Nature Climate Change*. Nature Publishing Group, 3(2), pp. 105–111. doi: 10.1038/nclimate1695.