Real Options Analysis of CO$_2$ transport and storage in the Southern and Central
North Sea under geological and market uncertainties and the viability of subsidies for
market development

Zhenggang Nie$^1$, Nasim Elahi$^1$, Anna Korre$^1$, Sevket Durucan$^1$, Shabana Ahmad$^2$, Ward
Goldthorpe$^2$

$^1$Department of Earth Science and Engineering, Royal School of Mines, Imperial College London,
London SW7 2BP, United Kingdom

$^2$The Crown Estate, 16 New Burlington Place, London, W1S 2HX, United Kingdom

Abstract

A multi-stage multi-scenario stochastic optimisation model of integrated CO$_2$ transport and storage
model developed by Elahi et al.$^{1,2,3}$ is used together with a CO$_2$ life cycle cost model developed by
Nie et al.$^4$ to examine future CO$_2$ storage optionality in the Southern North Sea to achieve UK Climate
mitigation targets. The combination of the two models allows for capturing the effects of storage cost
details on integrated whole system value chain design. The CO$_2$ feed for the first four time periods
2015-2035 is assumed to arrive at Easington until Bacton terminal also becomes an option for the last
3 time periods. The mitigation trajectory over the planning horizon is consistent with energy system
decarbonisation studies carried out by the Energy Technologies Institute$^5$. The development of a CCS
system is assumed to materialize around an anchor storage site while the role of depleted gas fields
is examined through whole systems optimisation. A portfolio approach allows exploration of the
trade-off between investment in storage sites in different locations vs. pipeline infrastructure and the
potential for linkage between multiple CCS hubs in different regions of the Southern and the Central
North Sea. As an example, to illustrate the approach, Block 5/42 is used as anchor case, along with
the Hewett and Leman gas fields and the Tay storage site to explore the potential trade-offs.

A scenario tree combines all possible outcomes between volatilities in the price of carbon and
uncertainties in the dynamic utilisation capacity and maximum injection rate for the portfolio of
storage sites as well as the availability of the storage sites across the time horizon. This results in five
distinct scenarios some of which share commonalities at some stages within the planning horizon.
The stochastic optimisation model provides insight for the investment and operational strategies for
deterministic stages which satisfy the requirements of all potential realizations of geological and
market conditions at minimum cost and distinguish the economic differences between the stochastic
stages hence highlighting the significance of a robust here-and-now strategy.

In addition to value chain planning considering the uncertainty relevant to the above attributes, a
meta-analysis is carried out for a range of scenarios to forecast the take-up of CCS based on the
anticipated time correlated with target rates of return for individual sites and the levels of capital and
operational subsidy support required to meet different policy objectives. The cash flow analysis of
the sites under the assumption of optimum integrated system planning, indicates that without subsidies when left to the free market even scenarios with larger assumed capacity for the anchor sites will not be able to achieve a viable business case before 2040 and by then the restrictions on the maximum injection rate will prevent the system to reach the desired mitigation target. Targeted subsidies for anchor sites are necessary to facilitate CCS uptake for surrounding sites and the transport operator.

The analysis demonstrates the economic complexity of CCS as a mitigation option, for a variety of potential realizations of capacity, injection rate, availability of storage site based on appraisal policies and the price of carbon. The methodology can be used to value and evaluate different options for policy formulation and transport and storage investments.

References


