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Accelerating Low carboN Industrial Growth through CCUS

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Scenarios for future storage requirements in the United Kingdom
A review of pathways of CO_2 capture and storage growth

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Executive summary

Estimates of possible rates of Carbon Capture and Storage (CCS) deployment to 2050 and beyond are required to identify credible options for geological storage of carbon dioxide (CO_2). This report reviews and summarises available estimates of CCS development for low-carbon industrial operations and large-scale hydrogen production to achieve continuing reduction of CO_2 emissions to meet national targets in future carbon budgets. We combine these estimates to develop a range of CO_2 capture rates for two industrial regions, Grangemouth and Teesside, to identify the required storage capacity that will be needed in future decades.

The UK Clean Growth Strategy, published in October 2017 by the United Kingdom's Department for Business, Energy and Industrial Strategy (BEIS), sets out actions that the UK Government can take to increase economic growth with lower carbon dioxide emissions. The UK has legally binding carbon budgets which have been fixed over five-year periods, with the first period from 2008-2012. The UK is in its third carbon budget period, from 2018 to 2022. Whilst the UK has met its targets in each of the first three periods, meeting the target in the subsequent fourth and fifth periods will require further significant technological transitions across many key sectors. These technology changes are most notable in the industrial, transport and heating sectors. Analysis by the UK Government Climate Change Committee indicates that the use of capture and storage of CO_2 from industrial sources will be required as part of a portfolio of options, to enable the UK to meet its fourth and fifth carbon budgets. The emissions reduction would be achieved by conventional power generation with CCS (up to 4-7 GW electricity generated) and capture of CO_2 from industrial plants (3-5 Mt CO_2 per year) by 2035. This review extends the timescale to 2100 since it is expected that once investments are made the infrastructure will provide low-cost options for continued CO_2 reduction in the latter half of this century.

An estimate of the potential magnitude and rate of future CCS deployment is presented, based on industry predictions of CO_2 capture from industrial sources and implementation of hydrogen reformation with CCS, available to May 2018. Providing this estimate allows CO_2 supply curves to be defined and a portfolio of suitable storage sites with matched capacity to be selected and appraised. However, assessing the future growth in energy demand must incorporate a range of factors including: future scale and locations of industrial emissions; proportion of fossil-based power and heating that might contribute to meet industrial demand; and possible rates of hydrogen replacement of natural gas for heating or transport. Since these factors carry large uncertainties, a scenario-based approach has been taken, whereby studies undertaken elsewhere have been reviewed and combined to develop an estimate of possible future CCS deployment, with a focus on the Teesside and Grangemouth industrial clusters.

Regional CCS deployment concepts were integrated and mapped onto a low-carbon development pathway at the Teesside and Grangemouth industrial clusters. In order to encompass different possible rates of CCS deployment in the UK, three variants along the pathway were defined with low, intermediate and high rates of CCS deployment. The variants reflect both increasing capture of CO_2 from industrial sources across a wider catchment surrounding the industrial clusters at Teesside and Grangemouth, and increasing production of hydrogen from methane with CCS. The pathway progresses from an '*initial projects*' phase through a '*growing projects*' phase to a '*maturing projects*' phase, to help achieve a low-carbon economy in the UK. Development considers the parallel operation of several CCS projects with progressively increasing cumulative geographical extent with increasing annual volumes of CO_2 stored. The 'maturing projects' phase will be further developed to consider future UK storage of CO_2 captured and transported from Europe.

Low rates of CCS deployment during the *initial projects* phase includes CO_2 capture rates at Teesside of 0.7 million tonnes (Mt) per year and at Grangemouth of 1.7 Mt per year. Storage capacities required for these initial projects are approximately 23 Mt and 61 Mt by 2055, respectively.

At intermediate rates of CCS deployment during the g*rowing projects* phase there would be industrial capture from more emitters and at higher rates together with increasing hydrogen production. Annual

CO_2 capture rates would increase to approximately 14 Mt per year at Teesside and 8.6 Mt per year at Grangemouth. Growing projects would require the provision of a total CO_2 storage capacity of 309 Mt for Teesside and 267 Mt for Grangemouth and Central Scotland by 2055. Assuming constant capture thereafter to 2100, the combined required storage capacities would increase to a total of 1248 Mt.

At high rates of CCS projects deployment, with increased hydrogen production, the average rate of CO_2 captured for storage in England would be 59 Mt per year. The CO_2 storage capacity required in 2050 would be approximately 852 Mt. Assuming constant capture rates thereafter, the required storage capacity would be 2557 Mt by 2100 for England. In this scenario, high rates of deployment for Scotland are being addressed by the ACT Acorn project.

The UK has an estimated theoretical potential CO_2 storage capacity of 78,000 Mt, well known from hydrocarbon exploration and production, underlying its immediately adjacent seas (Bentham et al., 2014). The three variants on the pathway to a UK low-carbon economy were investigated by the ALIGN-CCUS project for flexible storage options for growth of the Teesside and Grangemouth industrial clusters. The ELEGANCY project used the same pathway to examine seasonal and operational variations in CO_2 supply and composition associated with large-scale hydrogen production.