

BiGGAR Economics

Underground Coal Gasification: Economic Impact Assessment

A report to



CLUFF
NATURAL
RESOURCES

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1 EXECUTIVE SUMMARY

This report considers the potential economic impacts associated with Cluff Natural Resources' proposals to develop Underground Coal Gasification (UCG) projects at Kincardine (its initial project), elsewhere in the Firth of Forth and across the UK, and the long-term benefits that this could deliver for both the Scottish and the wider UK economy. The key findings of the analysis are summarised below.

The successful deployment of UCG at Kincardine could be the first step in the development of an entirely new industry in the UK that could generate more than £12.8 billion Gross Value Added (GVA) for the UK economy over the long term. It is estimated that the sector could also support an average of around 7,500 UK jobs but that this could reach around 11,900 jobs during the peak year of operations.

This report only considers two main potential end uses for syngas (the product of the UCG process): as a fuel for power generation and as a feedstock for the chemicals industry.

If used to fuel power generation syngas could help to generate a temporary construction related benefit of £1.2 billion GVA for the UK economy and support around 4,000 temporary construction jobs. It could also support a further 570 permanent jobs and generate a further £203 million GVA/year for the UK economy once the new power stations are fully operational.

Alternatively, if used as a feedstock for the chemicals industry, syngas could help to safeguard around 4,800 jobs which rely on the Scottish chemicals sector and safeguard between £307 and £732 million GVA for the Scottish economy.

The starting point for the analysis was to consider the economic benefits associated with the initial UCG project at Kincardine. These benefits included both the direct activity and employment supported on-site and the indirect benefits further down the supply chain. It was estimated that this project alone could generate a total benefit of around £603 million GVA and support an average of more than 350 jobs over the long term.

The next step of the analysis involved considering what could happen if successful deployment at Kincardine were to stimulate further investment in other UCG projects elsewhere in the UK. This was done by considering the level of economic activity that could be directly and indirectly supported by seven other potential UCG projects that have already been identified and licenced elsewhere in the UK. This could be considered a very conservative approach, because if the Kincardine UCG project demonstrates that the technology can be successfully and profitably deployed in the UK, further licences are likely to be granted to cover other areas of the UK's unused coal deposits.

It was found that the direct and indirect benefits to the UK economy that might be associated with these projects could amount to £5.6 billion GVA over the long term. It was also estimated that these projects could support an average of around 3,300 (direct and indirect) jobs over the long term. It is anticipated that this employment impact could peak at around 6,100 jobs around 10 years after operations commence at Kincardine before reaching a steady state of around 3,910 jobs.

Although several countries are exploring the potential of UCG technology, there is currently only one commercial scale UCG plant in the world. This means that should the UK manage to achieve large-scale commercial deployment of UCG technology the companies involved would gain a first mover advantage in the

global market. This should create valuable export opportunities for UK based companies involved in the UCG supply chain.

It was estimated that in 30 years time these exports could amount to around £558 million per year and the total value of export sales over the long term could amount to £2.8 billion. In 30 years time this activity could be generating almost £440 million GVA/year for the UK economy as a result of increased activity within UCG suppliers and indirect effects further down the supply chain and be supporting around 7,800 UK jobs. Over the long term this could represent a total contribution of £6.6 billion GVA for the UK economy.

Taken together the direct and indirect impacts of domestic projects and the impacts generated by future export sales could generate £12.8 billion GVA for the UK economy during the development of the industry over the next 30 years and support an average of around 7,500 jobs (peaking at around 11,900 during the peak years of operation).

The final stage of the analysis was to consider the potential uses for syngas (the product of UCG) and how this might support other sectors of the UK economy.

One of the potential end uses for syngas is as a fuel for power generation. To use syngas in this way it would be necessary to construct and then operate power stations specifically for this purpose. It was estimated that constructing these power stations could generate £1.2 billion GVA for the UK economy and support around 4,000 temporary construction jobs. Once fully operational the power stations could support around 570 permanent jobs and generate a further £203 million GVA/year for the Scottish economy.

Alternatively syngas could be used as a feedstock for the chemicals industry. The main opportunity for this would be at Grangemouth, where the decline of North Sea gas represents an on-going threat to future viability. If syngas were to be used in this way it could safeguard 2,800 jobs in the Scottish chemicals industry and between £307 and £732 million GVA/year for the Scottish economy. The impact across the UK could be greater if the wider UK chemicals sector benefited from feedstock produced at other UCG sites.

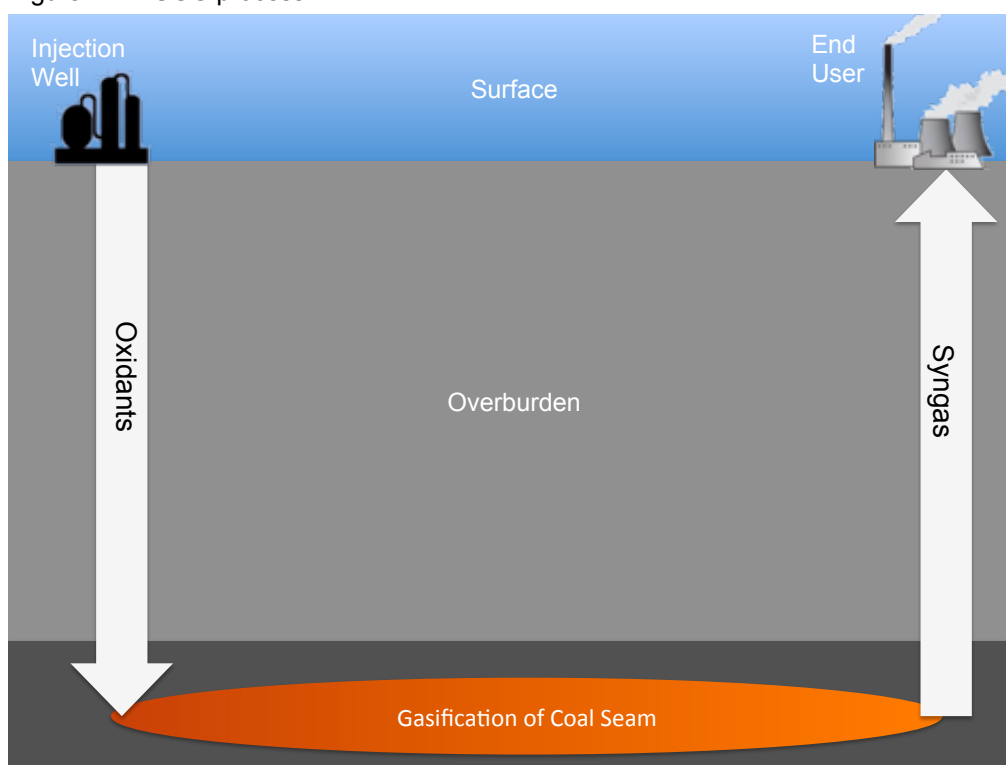
2 INTRODUCTION

This is a report by BiGGAR Economics that considers the potential economic impact of Cluff Natural Resources' proposals to develop a commercial scale Underground Coal Gasification (UCG) project under the Firth of Forth, and the implications for the future development of the sector.

2.1 Underground Coal Gasification

UCG is an industrial process (see Figure 2-1) that involves the partial combustion of underground coal seams in situ to produce a gas mixture known as syngas, which can be used as a chemical feedstock or as a fuel for power generation. Coal gasification is not new, with an analogous process used to produce "town gas", which was widely used for heating, lighting and cooking prior to the discovery and development of natural gas fields. Despite a long history and numerous pilot projects worldwide UCG technology has yet to be widely adopted, however recent technological developments have lead to renewed commercial interest in UCG globally.

Figure 2-1 – UCG process



Source: BiGGAR Economics

UCG allows the exploitation of otherwise non-mineable coal resources, has significant environmental benefits over conventional mining and lends itself particularly well to carbon capture and storage. With coal being phased out of the UK electricity generation mix and domestic natural gas production in decline, UCG has the potential to unlock huge untapped domestic coal resources, which could help to secure the UK's future energy supply and reduce reliance on imported gas.

2.1.1 Commercialisation of Syngas

The gasification of coal produces a 'syngas' which is primarily a mixture of methane (CH₄), hydrogen (H₂), carbon monoxide (CO) and carbon dioxide (CO₂). All syngas can be used as a fuel gas for primary electricity generation or for industrial applications requiring heat (i.e. steam boilers) or power (combined heat and power plants). Alternatively the syngas can be converted to various chemical intermediaries or end products via a range of chemical processes depending on the quality of the syngas, in particular the H₂/CO ratio, and local market requirements. These conversion products include:

- methanol and other petrochemical intermediates;
- ultra low sulphur diesel and aviation fuels;
- ammonia based fertilisers; and
- synthetic natural gas

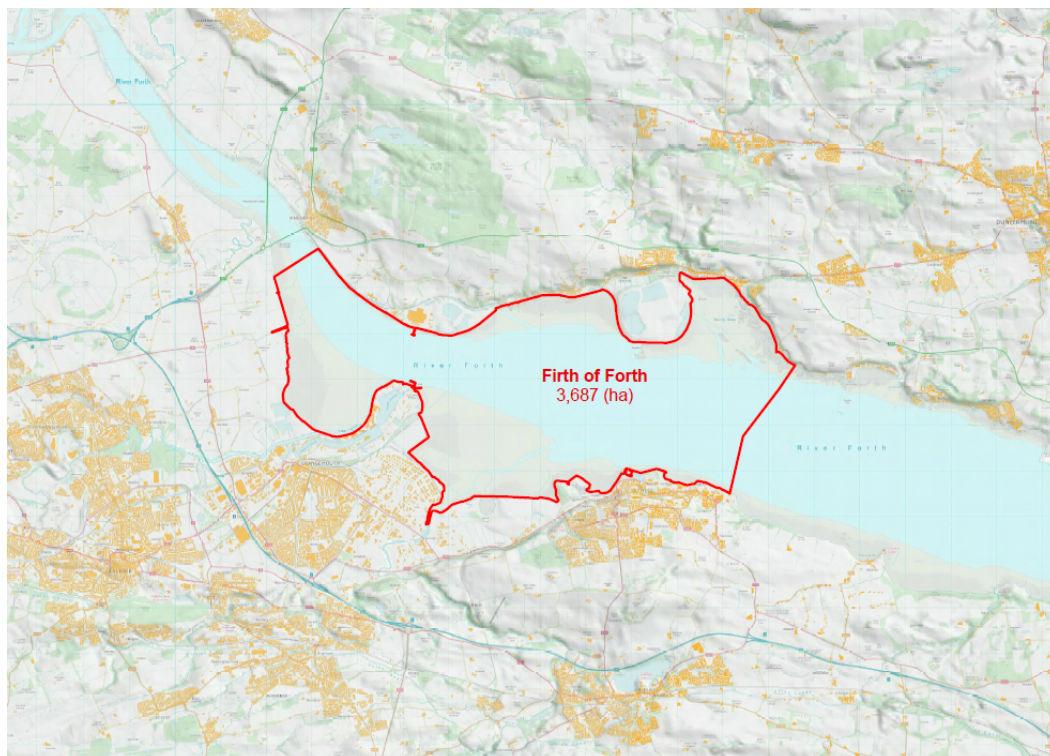
For the purposes of this report only primary electricity generation via a new build syngas specific power station and/or the supply of syngas to an existing petrochemical facility have been considered.

2.1.2 Cluff Natural Resources and the UK UCG Market

Cluff Natural Resources is a UK based resources company that was founded in May 2012 and is investing in unlocking the energy potential of deep coal resources in the UK using proven UCG techniques. Cluff Natural Resources currently has 100% working interest in nine deep UCG licences in the UK covering approximately of 690km² of the Firth of Forth, the Dee Estuary, offshore Carmarthenshire, offshore Cumbria and offshore Durham. The map below illustrates the company's Kincardine project area, which covers an area of approximately 36.9km² under the Firth of Forth.

In addition to those licences held by Cluff Natural Resources a further 12 UCG licenses, held by two competitor companies, covering approximately 1,012km² are currently listed by the Coal Authority. A number of other offshore and onshore areas within the UK have also been previously licenced for UCG or identified as areas with UCG potential in various government or academic reports.

Figure 2-2 – Kincardine Project Area



Source: Cluff Natural Resources

2.2 Approach

The impacts considered in this report include:

- impacts associated with the development and operation of an initial UCG project at Kincardine. This includes:
 - the direct employment and economic value generated by on-site activity; and
 - indirect benefits generated by development and operational expenditure, for example activity supported within companies that would supply goods and services to the Kincardine site and activity supported by the expenditure of people who would work at the Kincardine site or within one of the companies that comprise its supply-chain.
- impacts generated by the deployment of UCG technology at other sites in the UK. This includes:
 - the employment and economic value directly supported by activity at the other UCG sites considered; and
 - impacts associated with the wider supply chain for the UK UCG sector – this includes both activity supported within the companies that would comprise the supply chain for the sector and activity supported by staff whose jobs would be supported by the direct development and operational expenditure at the other UK sites.

- impacts that would arise as a result of UK based companies exporting goods and services to UCG developers elsewhere in the world as part of the global UCG supply chain. This includes:
 - direct employment and economic activity supported within companies that could export UCG related goods and services; and
 - indirect employment and economic activity generated by the expenditure of these companies and their employees elsewhere in the economy.
- impacts associated with the use of syngas. This includes:
 - activity that could be supported if syngas were to be used as a fuel gas for power generation, i.e. the jobs and economic activity that could be generated by the construction and operation of additional power stations; and the impacts generated by the expenditure of staff working in these power stations; and
 - jobs and economic activity that could be safeguarded if syngas were to be used as a chemical feedstock.

For illustrative purposes we have considered the longer-term impacts over a 30-year period. This coincides with the operational life cycle of the proposed Kincardine project, however the lifespan of the overall UCG industry is likely to be much longer.

The impacts presented in this report are measured in two ways: employment and gross value added (GVA).

Impacts are presented for three study areas:

- Firth of Forth – which was defined as the area covered by the Local Authority areas of Clackmannanshire, Fife and Falkirk;
- Scotland; and
- UK.

Each study area is inclusive – i.e. impacts at the UK level include Scottish impacts and impacts presented at the Scottish level include impacts in the Firth of Forth area.

Throughout the report all turnover/GVA and GVA/employee ratios used are derived from the Annual Business Survey and all multipliers used were taken from the input-output tables published by the Scottish Government in 2014.

Scottish multipliers were used because these are more detailed and up to date than equivalent multipliers for the UK economy. As these relate to the whole Scottish economy it was necessary to adjust them to reflect the relative scale of the three study areas.

The economy of the Firth of Forth is smaller than that of Scotland and therefore the economic multipliers will be lower. The area is home to 10.8% of the Scottish population, however only 8.4% of Scotland's jobs are located in the Firth of Forth. Companies and individuals are more likely to purchase goods and services locally, where they can. Therefore more than 8.4% of purchases by companies and individuals in the Firth of Forth will come from the area. It was assumed that multiplier effects retained within the Firth of Forth area would be 40% of the total Scottish multiplier effect

The total multiplier effect across the whole UK economy will be greater than that of Scotland and previous work undertaken by BiGGAR Economics for Regional Development Agencies has taken the UK multiplier effect to be equivalent to 120% of the Scottish effect.

2.3 Report Structure

The remainder of this report is structured as follows:

- section three describes the economic impacts associated with the development and operation of the proposed UCG project at Kincardine;
- section four considers the potential long-term economic benefits that could be generated if the Kincardine UCG project were to lead to the development of a new UCG sector in the UK;
- section five describes the potential economic benefits to the UK from exporting UCG services and expertise developed in the domestic market;
- section six considers the potential implications for the UK chemicals sector if syngas were to be adopted and used as a feedstock for the chemicals industry;
- section seven describes the quantifiable economic benefits that could be generated from the adoption and use of syngas (the product of UCG) as a fuel for power generation in the UK; and
- section eight presents the summary of the analysis.

3 DEVELOPMENT AND OPERATIONAL IMPACTS

This section considers the core operations undertaken at the Kincardine UCG site and the economic impact of this activity. The economic impacts that are considered in this section include direct and indirect impacts associated with:

- the construction of the Kincardine UCG plant (CAPEX);
- the drilling of panels to extract the syngas (Drilling); and
- the operation of the Kincardine UCG plant (OPEX).

Direct impacts include the jobs and economic activity supported on-site while indirect impacts cover the impact of expenditure generated by the project elsewhere in the economy. This would for example include the impact of expenditure on goods and services purchased from suppliers and the impact of the expenditure of staff who's jobs are supported by the project.

3.1 Kincardine UCG Project

The licence acquired by CNR at Kincardine covers an area of 36.9 km². It has been estimated that total coal reserves at the site are likely to be around 335 million tonnes (of which 236 million tonnes is measured or indicated). Initial estimates suggest that around 43 million tonnes of the available reserves (i.e. around 18% of measured reserves) might be suitable for UCG and it is anticipated that around 60% of this might be recoverable using current technology. Based on an active production time-scale of around 26 years, this implies that the Kincardine site could process around 1 million tonnes of coal/year.

3.2 Impacts

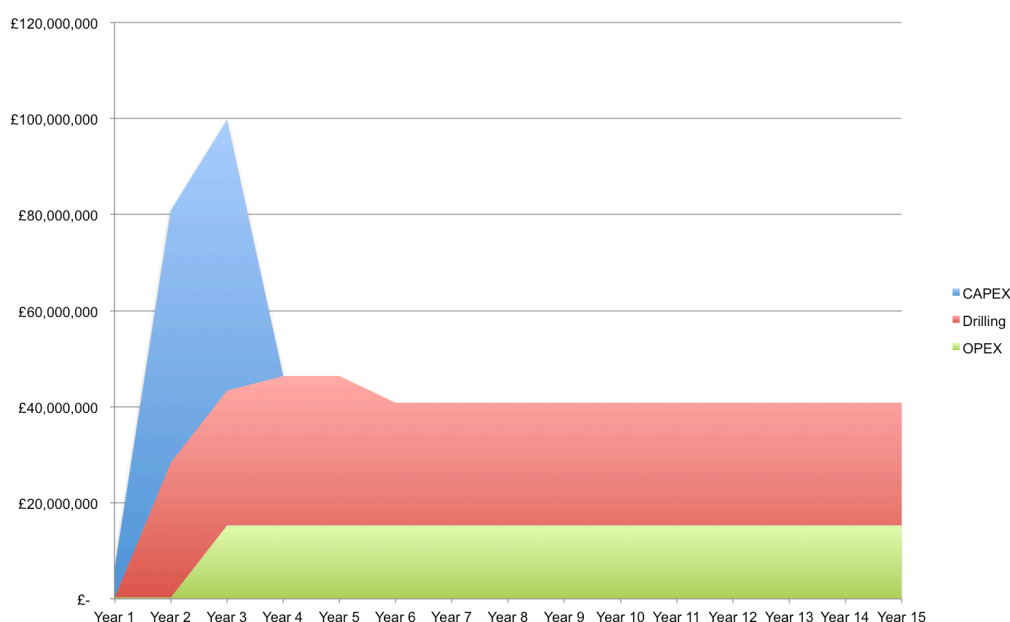
3.2.1 CAPEX and OPEX

The economic impact of the Kincardine project will depend on the pattern of investment at the site. The development of the site will result in significant capital expenditure (CAPEX) in the first six years as shown in Figure 3-1. It is estimated that the total capital expenditure would be £156.2 million (\$250 million). In a note from Panmure Gordon¹ the level of CAPEX is given, which shows that the CAPEX expenditure would peak in the fourth year of the project and the site would become fully operational by the fifth year. The operational expenditure (OPEX) would increase steadily in the first five years to £19 million and be maintained at that level during the operational lifetime of the project.

Figure 3-1 shows the expenditure profiles over time for the first 15 years of the development. This shows that the expenditure peaks during the CAPEX stage with a total expenditure in Year 3 around £100 million, before levelling out around £40 million per annum.

¹ Panmure Gordon & Co, Initiation of Coverage: Cluff Natural Resources, June 2014

Figure 3-1: CAPEX, Drilling and OPEX spending over time



Source: BiGGAR Economics based on data provided by Cluff Natural Resources

3.3 Stages of the development

There would be four main categories of expenditure involved in the development and operation of the Kincardine UCG plant. These are:

- Land;
- Drilling;
- Air Separation Unit (ASU); and
- Acid Gas Removal (AGR).

The total expenditure during the lifetime of the Kincardine UCG project is expected to be £1.2 billion. This will be split between the four main categories described above. The majority of the expenditure will be on drilling, which accounts for approximately 59% of expected expenditure.

Table 3-1: Supply chain for drilling process

	Proportion of supply chain
Land	0.5%
Drilling	59.0%
Air Separation Unit	30.2%
Acid Gas Removal	10.2%

Source: Cluff Natural Resources

The workforce and activities involved in each of these areas of activity is described below.

3.3.1 Land

One of the first activities to be undertaken would be the purchase of the land to be used for the development. The economic activity associated with a land acquisition is split between the value that the current landowners will get for the site and the activities of the professional services (lawyers, surveyors etc.) required to process the sale. This activity will need to be undertaken prior to any other activities being undertaken on the site.

3.3.2 Drilling

The drilling of panels will be a continuous operation to supply the oxygen required for the gasification process and to extract the products of this process. Throughout the thirty-year life span of this project, it is anticipated that 108 panels would be drilled. Each panel would have a life span of approximately three to five years before it is decommissioned.

Although UCG is very different from Hydraulic Fracturing, the supply chain involved in the drilling operations is likely to be similar in that similar expertise and equipment would be required. Studies undertaken by EY² have found that the majority of the expenditure will be on the specialist equipment and machinery that would be used in the drilling process. The disposal, storage and transportation of the waste products produced during the drilling process would account for approximately 12% of the supply chain expenditure. A summary of the full supply chain breakdown is given in Table 3.2.

Table 3-2: Supply chain for drilling process

	Proportion of supply chain
Equipment and machinery	62%
Waste disposal, storage and transportation	12%
Steel casing	7%
Rig Hire	7%
Ancillary equipment and services	4%
Cementing services	2%
Directional drilling services	2%
Drilling fluids and fluids engineering	2%
Drilling rig fuel	1%
Other	2%

Source: EY (April 2014), *Getting ready for UK shale gas*

The procurement of supplies for the drilling process will create long term opportunities for the manufacturing and engineering sectors. The EY report considered each area of the supply chain and the opportunity that these could present for companies in the UK. It found that in areas such as drill rig fuel and consulting services the UK had a business base that would be able to capture part of the drilling supply expenditure but that much of the specialised equipment and machinery would need to be procured from overseas. Analysis of findings of this report indicates that companies in the UK could secure around 62% of the total value of the drilling contracts. The proportion of these contracts that could be

² EY (April 2014), *Getting ready for UK shale gas*

secured at a more local level for the project was based on analysis of the Firth of Forth and Scottish economies and is shown in Table 3-3.

Table 3-3: Supply chain for drilling process

Proportion of supply chain	
Firth of Forth	34%
Scotland	48%
UK	62%

Source: BiGGAR Economics

3.3.3 Air Separation Unit

The Air Separation Unit (ASU) would be a physical construction on the site to house the workforce and activities involved in separating the oxygen from the air so that it can be used in the gasification process. This oxygen is sent down into coal seams to enable the gasification process to take place. Although air can be used in this process, by using pure oxygen the gasification process becomes more efficient, producing a higher quality syngas requiring less pre-treatment before commercialisation.

The CAPEX and OPEX associated with the ASU will both have different types of economic impacts. The construction of the ASU would create short-term opportunities for the construction and engineering sectors but the opportunities during the operation of the ASU would be different. The main cost involved with operating the ASU would be the cost of the energy used in the process, therefore the main economic impact would be through the energy supply chain.

3.3.4 Acid Gas Removal

The gasification process creates impurities, such as hydrogen sulphide, carbon dioxide and other acidic gases, which need to be removed from the gas output before it can be used. This process is called Acid Gas Removal (AGR).

This process will also take place in a physical structure that will be constructed on the site during the CAPEX stage of the development. As with the construction of the ASU, the construction of this facility will create short-term opportunities in the construction and engineering sectors.

The main cost associated with the AGR would be the labour costs associated with running the operation. This operation will also need specialist chemicals that would be sourced from elsewhere and a significant amount of energy. Therefore the operation of the AGR will create economic activity in the chemical and energy sectors.

3.4 Economic Impact of Kincardine Project

The economic impact of the Kincardine UCG project would include the direct employment and on-site activity supported by the project and the indirect impacts of expenditure associated with the project further down the supply chain.

3.4.1 Approach

The direct impact is that associated with activities of the on-site workforce. This was estimated based on data contained within Cluff Natural Resources' detailed

financial business plan for the site, which considers the level of expenditure by activity.

The direct economic impact was estimated by applying turnover/employment ratios³ for the appropriate sectors associated with each type of activity to the total amount of expenditure in each sector. Using this approach it was possible to estimate the direct employment supported by this expenditure. The GVA generated by this workforce was then estimated by applying the GVA/employment ratios for the same industries. This provided an estimate of the total direct GVA associated with the workforce described in the financial business plan.

The financial business plan included a significant proportion of activity that would occur off-site. To reflect this the direct activity was split between the Firth of Forth, Scotland and the UK in line with the proportions described in Table 3-3. This resulted in the direct core impact as described in Table 3-4.

Table 3-4: Direct Impact of On-site Operations at Kincardine

	Total GVA (30 yrs)	Peak annual GVA	Peak employment	Average employment
Firth of Forth	£182.7m	£13.3m	168	57
Scotland	£258.7m	£18.8m	238	80
UK	£337.1m	£24.5m	310	104

Source: BiGGAR Economics (totals may not sum due to rounding)

In order to capture the full economic impact of this expenditure economic multipliers were applied to the direct GVA and employment to estimate the impacts elsewhere in the supply chain and the impacts generated by employees spending their salaries. To capture both of these effects, the Type 2 multipliers from the Scottish Input-Output Tables⁴ were applied to the direct economic impacts. As discussed in section 2.2 the Scottish multipliers were adjusted for the Firth of Forth and the UK to reflect the comparative size of the economies in each study area. The impacts through the supply chain and the expenditure of employees salaries are provided in Table 3-5.

Table 3-5: Indirect Core Impact

	Total GVA (30 yrs)	Peak annual GVA	Peak employment	Average employment
Firth of Forth	£48.0m	£4.3m	94	45
Scotland	£169.9m	£15.1m	334	159
UK	£265.7m	£23.7m	522	249

Source: BiGGAR Economics (totals may not sum due to rounding)

3.4.2 Summary Kincardine UCG Project Impact

In total over the long term the Kincardine UCG project could generate almost £603 million GVA for the UK economy and support an average of around 350 jobs. It is anticipated that the activity supported by the project could peak around the middle of the first decade of operations at which time the project could be generating around £48 million GVA/year for the UK economy and supporting

³ ONS, UK Annual Business Survey 2013, 2015

⁴ Scottish Government, Input Output 1998 * 2012 Latest Year (2012), July 2015

more than 830 jobs. The impacts in each of the study areas are summarised in Table 3-6.

Table 3-6 - Summary Core Impact

	Total GVA (30 yrs)	Peak annual GVA	Peak employment	Average employment
Firth of Forth	£230.8m	£17.6m	263	102
Scotland	£428.6m	£33.9m	572	240
UK	£602.7m	£48.1m	833	354

Source: BiGGAR Economics (totals may not sum due to rounding)

4 LONG-TERM SECTOR DEVELOPMENT BENEFITS

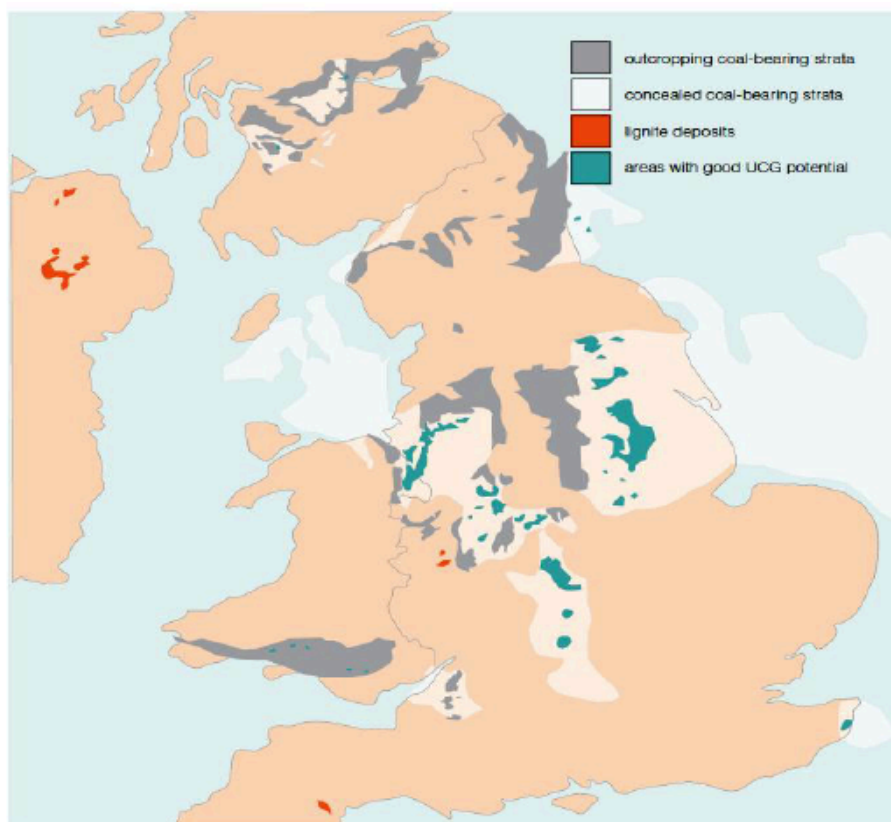
The previous chapter quantified the economic benefits that could be associated with establishing a new UCG project at Kincardine. This project is however only one of several similar potential developments in the UK. By demonstrating the potential of UCG technology it is hoped that the Kincardine project could stimulate investment in these other potential projects and support the development of a new UK UCG sector. The impacts associated with these other projects would include:

- direct impacts – i.e. employment and economic activity supported directly by the development and operation of the other UCG sites; and
- indirect impacts – i.e. employment and economic activity supported elsewhere in the UK economy as a result of expenditure associated with the development and operation of the other UCG sites. This would include activity supported within companies that supply goods and services to the sites and activity supported by the expenditure of staff whose jobs are supported by UCG development and operations.

4.1 Potential for UCG in the UK

According to a British Geological Survey Report from 2004⁵ a conservative estimate of coal in the UK that meets the main criteria for UCG is around 17 billion tonnes, in both onshore and near shore deposits.

Figure 4-1: Map of prospective areas of UCG



Source: Department of Trade and Industry (2004)

⁵ UK Coal Resource for New Exploitation Technologies (2004)

4.1.1 Other UCG Licences in the UK

In addition to the Kincardine licence area, an additional 20 active UCG licences covering approximately 1,665km² of known coal deposits are listed by the Coal Authority in the UK. Eight of these additional licences are held by Cluff Natural Resources while the remainder are held by two privately held companies. A number of other offshore and onshore areas within the UK have previously been licenced for UCG or identified as having significant potential for UCG in various government and academic reports.

All UCG licences are not equal in terms of coal geology or licence area and some licences are likely to be able to support much larger or much longer projects than that proposed for Kincardine area. For example an independent review of the Point of Ayr coalfield beneath the Dee Estuary highlighted an exploration target of between 980 and 1,230 million tonnes of coal potentially suitable for UCG, using the same cut-offs that define the 43 million tonne UCG project at Kincardine.

It is considered unrealistic to assume that every currently licenced area would eventually host a commercial UCG project and therefore a conservative approach has been taken to the development of the UK UCG industry over the next 30 years. For illustrative purposes this analysis has considered the potential impacts of seven additional UCG projects around the UK including:

- two other sites on the Firth of Forth of similar size to Kincardine;
- three sites elsewhere in the UK of a similar size to Kincardine; and
- two sites elsewhere in the UK three times the size of the Kincardine.

This limited role out would result in approximately 12 million tonnes of coal being gasified annually across the UK approximately a decade after work commenced on the Kincardine project. This could be considered a very conservative approach, because if the Kincardine UCG project demonstrates that the technology can be successfully and profitably deployed in the UK, further licences are likely to be granted to cover other areas of the UKs unused coal deposits.

4.2 UCG Investment Elsewhere in the UK

As with the initial Kincardine project, the impact of other UCG projects elsewhere in the UK will depend on the scale of investment required to bring each site into production and the value of on-going expenditure once the site is operational. The Kincardine project is the furthest advanced of all the potential UCG projects in the UK so details about the investment required to bring the other potential projects on-line are not yet available. It is however reasonable to expect that the type of investment associated with the other sites would be broadly similar to that required to bring Kincardine into operation. The starting point for estimating the investment required to develop and operate these other sites was to calculate the scale of potential production at each site relative to Kincardine. The total development and operational costs of each of the other UK projects was then estimated by applying this ratio to the total development and operational costs at Kincardine.

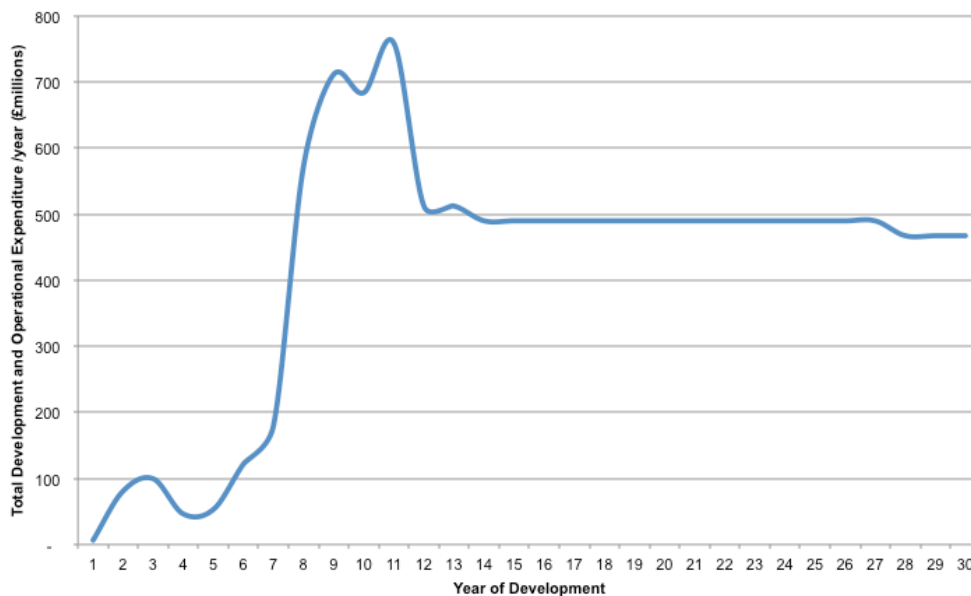
4.2.1 UCG Development Time-Scale

It was assumed that development of the other sites would be staggered, with each project starting between the middle to the end of the first decade of operations (after production at Kincardine begins). It was also assumed that once

investment started the expenditure profile at each site (i.e. the proportion of total expenditure expected to occur in each year of development) would be the same as for Kincardine.

Applying these assumptions suggests that the investment profile associated with the development of the UK UCG sector might look something similar to that depicted in Figure 4-2. This shows the initial investment associated with developing the Kincardine project during the early years of the first decade of operations before capital investment ramps up dramatically as development work on other projects begins toward the middle of the first decade of operations. It then indicates that capital investment might peak at around £718 million/year around the beginning of the second decade of operations as other projects begin to enter production before levelling off to around £449 million/year around the middle of the second decade of operations.

Figure 4-2 – Investment Profile for UK UCG Sector (including Kincardine UCG)



4.3 Impact of UCG Projects Around the UK

4.3.1 Direct Impact of Other UCG Projects in the UK

The direct impact of other UK UCG projects would include on-site employment and economic activity at the seven other UCG sites in the UK. This impact was estimated by applying turnover/GVA and turnover/employee ratios derived for the Kincardine project to the expenditure illustrated in Figure 4-2.

In this way it was estimated that over the long term the seven other UCG projects in the UK could directly generate £3.1 billion GVA for the UK economy. It was also estimated that over this period these projects could support an average of around 975 jobs, with peak employment of up to 2,027 occurring around 10 years after development begins at the Kincardine site.

Table 4-1: Direct Impact of UCG Projects Elsewhere in the UK

Study area	Total GVA (£m over 30 yrs)	Peak annual GVA (£m)	Peak employment (jobs)	Average employment (jobs)
Firth of Forth	521.4	29.8	343	163
Scotland	1,476.2	84.5	971	461
UK	3,120.9	187.7	2,027	975

Source: BIGGAR Economics (totals may not sum due to rounding)

4.3.2 Indirect Impact of Other UCG Projects in the UK

The indirect economic impact of other UK UCG projects would include off-site effects generated elsewhere in the supply chain. This would include the impact of expenditure on the goods and services required to develop and operate the sites and the impact of expenditure by staff whose jobs are directly supported by the projects.

The first step was to estimate the total indirect effects of other UCG projects in the UK. This was done by applying the ratio between direct and indirect effects for the Kincardine project to the direct effect estimated in the previous section.

Next it was necessary to estimate how much of this total indirect effect might occur in each study area. To do this it was then necessary to consider the location of each project and the likely location of the companies that might be involved in supplying each project with goods and services.

Analysis of the supply chain for the Kincardine project suggests that it might be possible to source 62% of supplies from companies in the UK and it was assumed that this would be the case for all the other potential UCG projects in the UK. The analysis undertaken of the supply chain for the Kincardine project also indicated that 48% of supplies might be sourced from companies based in Scotland. While it is reasonable to expect that this proportion would be similar for other Scottish UCG projects it is likely that projects elsewhere in the UK might source a lower proportion of supplies, perhaps 25%, from Scottish companies.

Similarly the analysis described in the previous chapter indicated that around 34% of the supply chain expenditure associated with the Kincardine project could be retained by companies based in the Firth of Forth area. Although it would be reasonable to expect that other UCG projects would also seek to source supplies locally if possible, because the Kincardine project will be the first UCG project to be developed in the UK this should help companies based in the area to develop a first mover advantage. This should enable companies based around the Firth of Forth to secure a disproportionate share of the contracts associated with other UK UCG projects.

This was modelled by assuming that 35% of the contracts secured by Scottish companies (for both English and Scottish projects) would be secured by companies based around the Firth of Forth. This implies that these companies could secure 17% of the total contract value of Scottish based projects and 9% of the total contract value of projects in England. These assumptions are summarised in Table 4-2.

Table 4-2 – Proportion of Contract Value Secured by Companies in Each Study Area

Location of Suppliers	Other Scottish UCG Projects	Other UK UCG Projects
Firth of Forth	17%	9%
Scotland	48%	25%
UK	62%	62%

Source: CNR. *estimated based on average measured and indicated resources/ha across other sites

By applying these assumptions to the total indirect effect it was possible to estimate that over the long term the indirect impact generated by other UCG projects elsewhere in the UK could amount to £2.5 billion GVA for the UK economy. It was also estimated that this activity could support an average of around 2,300 jobs across the UK, with peak employment of almost 4,100 jobs occurring around 10 years after development begins at the Kincardine site. These impacts are summarised in Table 4-3.

Table 4-3: Indirect Impact of UCG Projects Elsewhere in the UK

Study area	Total GVA (£m over 30 yrs)	Peak annual GVA (£m)	Peak employment (jobs)	Average employment (jobs)
Firth of Forth	137.5	8.7	219	128
Scotland	973.1	62.8	1,548	907
UK	2,469.5	163.2	4,116	2,301

Source: BiGGAR Economics (totals may not sum due to rounding)

4.3.3 Total Impact of Other UK UCG Projects

In this way it was estimated that over the long term the seven other UCG projects in the UK could generate £5.6 billion GVA for the UK economy. Of this it was estimated that £2.4 billion GVA could be retained in Scotland with around £0.7 billion GVA being retained in the Firth of Forth area. It was also estimated that over this period these projects could support an average of around 3,276 jobs, with peak employment of up to 6,143 occurring around 10 years after development begins at the Kincardine site.

Table 4-4: Total Impact of UCG Projects Elsewhere in the UK

Study area	Total GVA (£m over 30 yrs)	Peak annual GVA (£m)	Peak employment (jobs)	Average employment (jobs)
Firth of Forth	658.9	38.4m	543	291
Scotland	2,449.4	145.5m	2,442	1,368
UK	5,590.4	350.9m	6,143	3,276

Source: BiGGAR Economics (totals may not sum due to rounding)

The estimates presented above should however be regarded as conservative. The estimates presented above are based on the expectation that only around 18% of measured reserves (i.e. 43 million tonnes at Kincardine) might be suited to UCG and a recovery rate of 60%. These figures are both based on current technological expectations and do not take any account of the likely effect of experience and learning by doing. It is reasonable to expect that as the sector

matures those involved will be able to build on the experience gained during early projects to improve techniques, which should increase both the proportion of reserves that are considered suitable for UCG and overall recovery rates.

A useful parallel could be drawn here with the experience of the North Sea oil industry where, as time has passed and technology has improved, recovery rates have gone up and reserves that were once classified as “possible” or “probable” have gradually been reclassified as “proven”. Should the UCG sector follow a similar pattern of development (as might reasonably be expected) then it is likely that the proportion of reserves classified as suitable and the recovery rate currently anticipated would both increase, which would increase the total economic impact described above.

4.3.4 Potential Development Growth

This analysis considers the UCG sector growing for the first decade and the operational impacts associated with these developments, which cover approximately 3% of the UCG potential of the UK. In the event of the technology proving to be viable in the UK, there is potential for projects covering 2 or 3 times this scale to be developed over the coming decades.

Any increase in the number of UCG projects would have additional economic impacts across the UK. For example, if 6% of the UCG potential was developed over the coming decades this would mean that the sector could employ up to 8,500 people at its peak. Similarly if the sector developed 9% of the UCG potential over the coming decades, employment would peak at 12,900 people.

5 UCG EXPORT POTENTIAL

This section looks at the potential benefits to the UK economy if a strong UK based supply chain emerges to service an emerging global UCG sector.

5.1 Development of Export Sector

As the UK UCG sector matures UK based companies involved in the supply chain will develop specialist experience in UCG technology, which could be exported to other countries with UCG potential. In this respect the evolution of the UK UCG sector could reflect the UK Oil and Gas sector, which has significant export activity. In both markets the UK production opportunities are dwarfed by the international production potential. In both markets the UK sector also faces specific challenges that will enable it to develop specialism with international reputations.

The total direct sales in the supply chain for the Oil and Gas sector in the UK amounted to £35 billion in 2012, of which 40% was from exported goods and services⁶. This strong export base is built on specialist knowledge of subsea engineering and has enabled the domestic industry to remain buoyant through fluctuations of domestic demand.

Industry leaders expect export sales to rise in the coming decade as the domestic market contracts. It was assumed that as the export market matures, export sales will account for two-thirds of the total sales in the supply chain.

The development of a UCG demonstrator project at Kincardine would support the industry in the UK by capturing first-mover status in the global UCG sector. Although the technology for UCG has been in use since the early 20th century, the development of modern innovative solutions to the challenges faced in this sector would enable the sector to develop globally.

A recent example of this would be the onshore wind sector. Although wind energy has been used for centuries, developments in the technology in the latter half of the 20th century lead to the creation of the onshore and offshore wind sectors as we see them today. Countries such as Denmark were able to capitalise on the development of these technologies and have been able to benefit from their positions as first movers. Currently, 90% of the world's offshore wind turbines have been installed by Danish companies⁷ and the country aims to build on the reputation that it has gained in this industry to capture greater economic impact as the sector develops more widely.

The Kincardine project could enable the UK to capture a first mover advantage in the UCG sector by applying the local expertise from the offshore oil and gas subsea engineering sector to develop solutions to the issues that have led to the UCG industry struggling in other countries. Australia and Canada have both had demonstrator projects that have operated since 2000, however in neither case have the demonstrators resulted in the industry being developed much further. Technologies that enable the demonstrator project to develop into the creation of a national industry in the UK would attract the attention of other interested countries.

⁶ Oil & Gas UK (2015), Activity Survey 2015

⁷ Ministry of Foreign Affairs of Denmark, <http://denmark.dk/en/green-living/wind-energy/> (accessed 17/08/2015)

5.2 Global UCG Market Potential

The UK represents a small fraction of the global potential and activity associated with UCG. There has been significant historic interest in UCG particularly in the former USSR however the discovery of natural gas in the USSR attracted more interest and investment in UCG fell away. At the moment there is only one commercial UCG operation in the world, located in Uzbekistan. The plant produces 1,000,000 m³ of syngas a day which is used to produce electricity by co-firing syngas in a large coal fired power station.

The global potential for UCG is significant and several countries with significant coal resources have considered the potential for UCG extraction. In the past 20 years there have been several test sites in Australia and New Zealand. The last of these closed in 2013. South Africa also has large coal resources and UCG is currently being promoted as a means to economically extract energy there. One demonstration UCG site was in operation between 2007 and 2011 and there are a number of other sites that are being considered for further UCG development.

The world's largest producer of coal, China, is also involved in the development of UCG projects. There are approximately 30 on-going projects that focus on gasification within man made caverns and abandoned mines, as opposed to underground seams that have not been accessed previously.

If the technology can be proven there is significant potential for worldwide application. The World Energy Council puts global proved (economically recoverable) coal reserves at about 891 billion tonnes (403 billion tonnes bituminous, 287 billion tonnes sub-bituminous, and 201 billion tonnes lignite)⁸. However, as full studies have not been carried out in many parts of the world and there are significant coal deposits that are not economically recoverable with current technology this is likely to be an underestimate.

The BP Statistical Review of Energy provides an estimate of potential coal reserves by country. Not all countries will have the opportunity to utilise their coal through UCG but the countries that are currently exploring UCG technologies would represent a significant market. The combined coal reserves in China, South Africa and Australia alone is for example over 221 billion tonnes – almost 1,000 times the amount of potential reserves available at the Kincardine site.

Table 5-1: Potential Coal Reserves

Potential Coal Reserves (Bt)	
China	114.5
Australia	76.4
South Africa	30.2
USA	237.3
Canada	6.6
Total	465.0
UK	17.0

Source: BP Statistical Review of Energy, 2015

⁸ World Energy Council (2013)

5.3 Potential Value of Global UCG Supply Chain

As discussed in section 4.1.1 it is currently anticipated that around 18% of the measured reserves at the Kincardine site might be suitable for UCG and around 60% of these reserves might be recoverable using current technology. Applying these assumptions to the estimates presented in Table 5-1 indicates that there could be around 51.2 billion tonnes of coal reserves in the five main UCG markets around the world that could be recovered using current UCG technology. Multiplying this by the average cost/tonne of coal reserves recovered at Kincardine suggests that recovering these reserves would require a total investment of around £2,430 billion.

However, as with the UK UCG market, only a proportion of the coal in these global deposits will be in areas that licences are likely to be awarded for and companies are willing to invest in. If these global markets were able to gasify just 3% of their coal deposits, similar to the UK in this analysis, the total expenditure involved in this process would be over £300 billion.

5.3.1 Potential Export Value

Analysis of the UCG supply chain undertaken in chapter 3 indicates that at the time of writing the UK may be in a position to secure around 62% of the total expenditure required to develop and operate the Kincardine site. This implies that 38% of supplies would need to be sourced from overseas.

At present there is no commercial UCG sector in the UK (or anywhere else in the world) so it is likely that the current state of development within the UK supply is similar to what might be expected elsewhere at the outset of the development of the sector. That is to say, should China, South Africa or Australia take a decision to develop a UCG sector next year, it would be reasonable to expect that domestic companies might secure 62% of the total expenditure required to do this.

This implies that 38% of supplies would need to be sourced from overseas. Applying this assumption to the total market value discussed above suggests that the total UCG export market could be worth £118 billion.

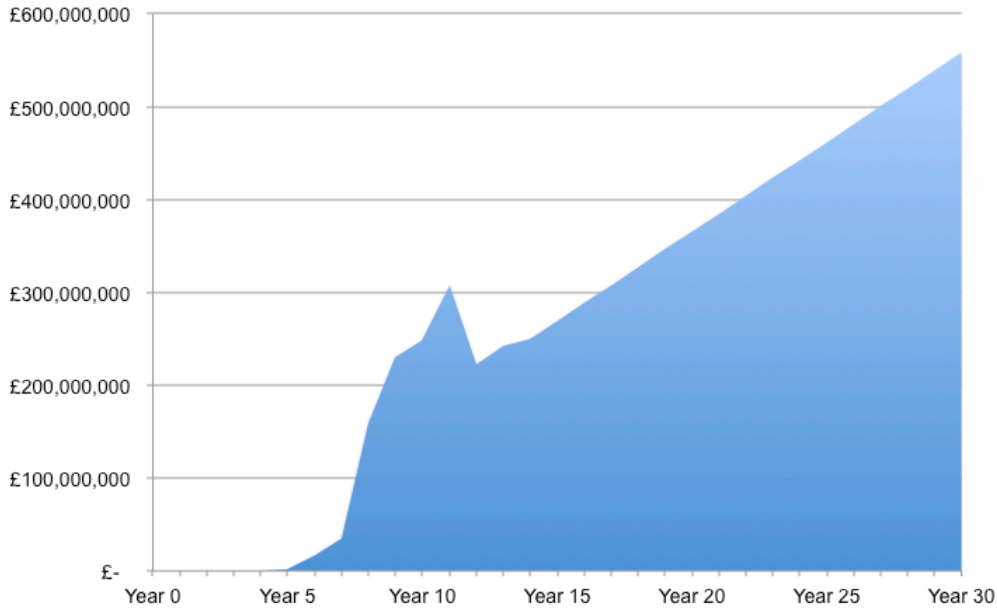
The proportion of this market that could be secured by UK based companies would depend on a variety of factors and is not possible to estimate with any certainty at this stage. As discussed in section 5.1, development of the Kincardine site and subsequent development of a UK based UCG sector would however give companies a distinct first mover advantage, which should enable them to secure a strong market position in the global UCG export market.

In order to model the potential value of this market to UK companies it was assumed that the evolution of the UK UCG sector might closely mirror the evolution of the UK oil and gas sector. Data from Oil and Gas UK suggests that export sales are expected to account for two-thirds of total oil and gas sector turnover in the coming decade. It was therefore assumed that once the UK UCG sector is fully mature (which was assumed to occur early in the third decade of operations) export sales would represent a similar proportion of total sales. This implies that in 30 years time UK based companies could be supplying exports with an annual value of around £558 million to the global UCG market.

5.4 Economic Impact

In order to estimate the economic impact associated with export sales it was first necessary to consider how the UK export market might develop over time. To do this it was assumed that export sales would steadily increase from early in the first decade of operations until it accounts for two thirds of the total turnover of the sector at around the beginning of the third decade of operations. This growth is illustrated in Figure 5-1.

Figure 5-1 – Export Sales Over Time



These proportions were then applied to the total (direct and indirect) impact of the domestic UCG sector in each study area in order to estimate the total economic impact of export sales. In this way it was estimated that over the long term UCG exports could contribute £6.6 billion GVA to the UK economy. In 30 years time this could equate to an annual economic contribution of £440 million GVA and around 7,800 jobs. These impacts are summarised in Table 5-2.

Table 5-2: Summary Export Impact

	Total GVA (30 yrs)	Peak annual GVA	Peak employment	Average employment
Firth of Forth	£773.8m	£51.8m	674	338
Scotland	£2,867.6m	£191.6m	3,227	1,607
UK	£6,584.9m	£440.3m	7,820	3,881

Source: BiGGAR Economics

5.4.1 Impact in context

It is worth comparing these export figures with the size of the global market over this time period. If the global sites were developed in a similar time frame to the UK UCG developments, the sector in the UK would account for up to 12% of the global market. This proportion of market share would require the UK to take advantage of any first mover status in the early stages of the sector's development.

6 SAFEGUARDING THE SCOTTISH CHEMICALS SECTOR

The significant production of H₂ and CO via the UCG process means the other obvious use of syngas, especially in a Scottish context, is the use of syngas as a feedstock for the existing petrochemicals industry. This chapter describes the benefits that could be generated for the Scottish economy if syngas were to be used in this way. There could be a similar case made elsewhere in the UK associated with other UCG sites.

6.1 Scottish Chemicals Sector

According to data published by the Scottish Government, in 2012 (latest available figures) chemical manufacturing generated around £568 million GVA for the Scottish economy and provided direct employment for around 5,800 people⁹. This represents around 5% of the total value of the Scottish manufacturing sector.

A major component of the Scottish chemicals sector is the petrochemicals plant and oil refinery at Grangemouth. The total on-site total employment in both sectors in Grangemouth is around 1,370. In addition to this around 2,000 contractors are believed to work on site¹⁰.

Government statistics¹¹ show that the chemicals industry employs a total of 2,800 people in Falkirk, most of which will be either directly or indirectly supported by the petrochemicals industry at Grangemouth. Taken together it can therefore be estimated that Grangemouth directly and indirectly supports at least 4,800 Scottish jobs.

Declining output from the North Sea is a major and on-going threat to the future of the chemicals sector in the UK. The reduction in the availability of chemical feedstock has meant that the industry is increasingly looking elsewhere for gas. The most common new source of feedstock is from shale gas, which is produced in North America. It is however expected that increased demand from US buyers and the cost of liquefying the gas for transportation will mean that this is unlikely to remain cost effective in the long term.

6.2 Potential Contribution to the Scottish Chemicals Sector

CNR has an interest in several UCG licence areas around the UK but has chosen to develop the Kincardine project first. One of the main reasons for this is because the Kincardine site is located very close to Grangemouth, which is a potential end user of syngas.

Grangemouth is home to Scotland's only crude oil refinery, which produces the majority of fuels used in Scotland. The site is also home to a major petrochemical sector, which breaks down gas to manufacture around 1 million tonnes of petrochemical products each year. These products are used as the building blocks in the manufacture of a vast range of other products including bottles and pipes, cabling and insulation, food packaging and pharmaceuticals.

⁹ Scottish Government (2014), Annual Business Statistics 2012 (SIC 20 - manufacture of chemicals and chemical products (data reporting issues means that this is likely to be an under estimate of the total value of the sector).

¹⁰ BBC (23 October 2013), Grangemouth dispute: Ineos says petrochemical plant will close

¹¹ Scottish Government (2015), Annual Business Survey

The development of UCG at Kincardine represents an opportunity to develop an indigenous source of fuel gas and feedstock for Grangemouth and safeguard activity at the site. It is understood that the range of petrochemical plants co-located at Grangemouth currently consume around 200 tonnes of hydrogen per day and it is estimated that the syngas produced by the Kincardine project could be used to provide around 150 tonnes per day.

As the cost of hydrogen produced at Kincardine is expected to be significantly lower than the cost of hydrogen produced using imported gas, this could make a substantial difference to the cost of production at Grangemouth. This could help to ensure that Grangemouth can maintain a competitive advantage in the global petrochemicals market and secure the long-term future of the sector in Scotland.

6.2.1 Safeguarding the Scottish Chemicals Sector

In 2012 (the latest year for which figures are available) the chemicals sector in Falkirk generated £307.3 million GVA for the Scottish economy. Securing the future of the Grangemouth petrochemicals plant would help to safeguard this economic activity for the future. It is however possible that securing the competitive position of the plant could help to increase this economic contribution.

Analysis of Scottish Government statistics shows that GVA/employee in the Scottish chemicals sector has fallen substantially over the past few years, from a peak of £261,000/employee in 2010 to just £97,000 in 2012. Over the same period employment in the chemicals sector in Falkirk has fallen by around 11%. It is likely that these changes are (at least partly) attributable to the long-term competitive decline of the sector.

The development of a UCG project at Kincardine represents an opportunity to produce a (relatively) cheap, reliable indigenous source of hydrogen, which could help to reverse the competitive decline witnessed in recent years. It is too early to estimate with any certainty what the implications of this could be for the Scottish economy; however, it is instructive to consider the previous performance of the Scottish chemicals sector.

As described above GVA/employee in the Scottish chemicals sector peaked at £261,000/employee. If the opportunities presented by UCG at Kincardine were to enable the sector to return to this level of competitiveness then the value of activity safeguarded could amount to as much as £732.0 million GVA.

Table 6-1: Summary Contribution to Scottish Chemicals Sector

	Jobs safeguarded	Annual GVA safeguarded (£m, current)	Annual GVA safeguarded (£m, potential)
Firth of Forth	4,800	307.3	732.0

Source: BiGGAR Economics

7 SYNGAS USE – POWER GENERATION

Should UCG be widely adopted across the UK it is considered likely that the majority of syngas produced would be used in new build, high efficiency gas turbines for the production of primary electricity. There is a legal presumption that any new build generation capacity built to consume UCG derived syngas would have to include CCS or at least be CCS ready.

This chapter considers the benefits to the UK economy that could be realised if syngas were to be used in this way.

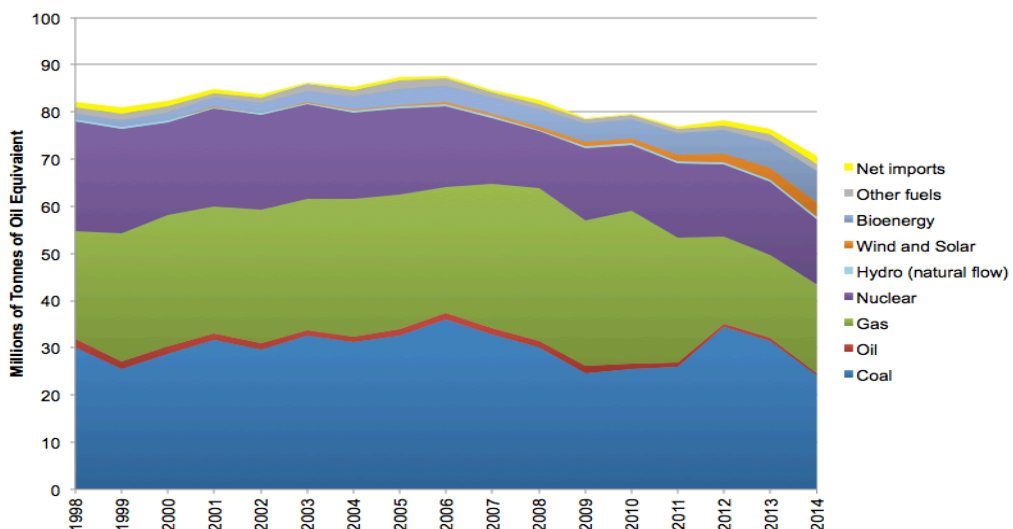
7.1 The UK Energy Market

In 2014 coal accounted for 34% of the fuel used for power generation in the UK (Figure 7-1), making it the single most important source of fuel for power generation in the UK. Importantly, despite the decline of coal as a source of final energy consumption, its importance as a source of fuel for power generation has been relatively stable.

The introduction of the 2008 Climate Change Act means that the UK Government is now under a legally binding obligation to reduce the UK's greenhouse gas emissions by at least 80% (from the 1990 baseline) by 2050. This means that pressure to encourage power producers to switch away from coal toward cleaner fuels is now higher than ever.

The substantial timescales required for the deployment of renewables or new nuclear capacity means that as reliance on coal reduces, an increasing proportion of demand is expected to be filled by natural gas. Domestic production of natural gas has however been in decline for more than a decade. As this decline continues the UK will therefore become increasingly dependant on imported gas to fuel power generation. This presents clear geopolitical and economic challenges for the UK.

Figure 7-1 - Sources of Fuel for Power Generation in the UK



Source: DECC (2015)

7.2 Longannet

The Firth of Forth is home to Scotland's largest power station, Longannet, which is currently operated by Scottish Power and has an installed capacity of 2.4GW. Longannet Power Station was opened in 1972 but it has been announced that site will close in March 2016¹². The closure of Longannet will see the end of coal power generation in Scotland (Scottish Power closed the Cockenzie Power Plant in East Lothian in 2013).

The closure of Longannet power station is likely to have economic impacts beyond the 236 directly employed staff. In 2012 Scottish households consumed 10.9 Twh of electricity and in the same year Longannet produced 9.5 Twh of electricity. Therefore, Longannet produces approximately 87% of the domestic household energy demand in Scotland.

Not all of the energy produced at Longannet is consumed in Scotland and the station contributes towards Scotland's electricity surplus. In 2012 Scotland exported 12.9 Twh¹³ of electricity to the rest of the UK and beyond. The removal of the electricity provided by Longannet will increase the likelihood of Scotland moving from a net exporter to a net importer of electricity from 2016.

In addition to the 236 staff directly employed at Longannet the closure is likely to have an impact on the wider supply chain for the power station. In 2012 Longannet procured 47% of its coal (2 million tonnes) from Scottish suppliers, which is equivalent to 45% of all Scottish coal production in 2012¹⁴. Scottish coal production has dipped significantly since then due to significant company closures and in 2014 Scotland produced 2.5 million tonnes of coal. The lack of demand for Scottish coal from Longannet is likely to further threaten the future viability of the coal industry in Scotland.

7.3 Kincardine Power Generation

It is expected that the syngas produced at the Kincardine UCG plant would be sufficient to power the equivalent of a 300MW thermal power plant. As there is currently no power plant in the local area that is designed to use syngas as a fuel a new plant would need to be constructed if syngas were to be used in this way. The impact associated with this would occur during the construction of the power plant and during its operational lifespan. It was assumed that any new power plant that might be built to use the syngas produced at Kincardine would be located in the Firth of Forth area to minimise the transportation requirements for the processed syngas.

The economic impact of the construction phase would depend on the amount of capital expenditure required to develop a new power station. It is understood that this could amount to around £250 million excluding the cost of any associated CCS infrastructure which would be required to transport CO₂ from the UCG production site to the proposed Feeder 10 pipeline which is planned to take CO₂ from the central belt of Scotland to the Goldeneye CCS project off Peterhead.

The direct economic impact of this expenditure was estimated by applying turnover/GVA and GVA/employee ratios for the areas of the construction sector

¹² Scottish Power – Press release *Longannet Power Station to Close in March 2016*, 18/08/2015 – accessed 18/08/2015

¹³ Scottish Government, *Energy in Scotland 2014*, 2014

¹⁴ BGS, *Surface Coal Mining Statistics 2014*

that specialise in utility projects. The indirect impact of this expenditure was then estimated by applying appropriate multipliers. In this way it was estimated that during the construction phase, a new power plant could support 308 jobs in the Firth of Forth and generate £95.1 million GVA during the construction period. Across the UK this impact could amount to almost £153 million GVA and 500 jobs.

The economic impact of a new power station during the operational phase was estimated based on anticipated employment levels. Evidence from other power stations elsewhere in the UK suggests that typical employment at a power station would be of the order of 50 employees. The direct economic impact associated with this level of employment was estimated by multiplying the number of direct jobs by average GVA/employee in the UK electricity production sector.

The largest area of expenditure within the supply chain for any new power station would be the syngas fuel. The economic impact associated with the syngas fuel has already been considered in this report and therefore the indirect supply chain impacts were excluded from this analysis to avoid double counting. However, the induced impacts associated with the expenditure of the staff directly employed on the site were included. This was done by applying Type 1 employment and GVA multipliers to the direct GVA and employment effects.

In this way it was estimated that the power plant could support 57 permanent jobs in the Firth of Forth and generate £4.1 million GVA/year once fully operational. These impacts are summarised in Table 7-1.

Table 7-1: Summary Power Generation Impact - Kincardine UCG (300 MW)

	Construction		Operational (Annual)	
	Jobs	GVA	Jobs	GVA
Firth of Forth	308	£95.1m	57	£4.1m
Scotland	451	£138.2m	68	£4.8m
UK	498	£152.6m	72	£5.1m

Source: BIGGAR Economics

7.4 UK Opportunity for Syngas Power Generation

The development of a 300MW power plant in the vicinity of the Kincardine project would represent a small proportion of the opportunity presented if the full UK UCG resources were utilised.

To model the potential scale of this benefit across the UK it was assumed that the power generation potential of the other UCG projects would be similar to the Kincardine project (in reality some of the other projects are much larger than Kincardine so this is likely to be an under estimate).

The Kincardine UCG project is based on a site with an estimated coal consumption of 1 million tonnes per annum. This production is expected to be sufficient to produce enough syngas to power a 300MW power plant. This implies that every UCG site of a similar size to Kincardine could support a power plant of a similar size. The additional 7 UK UCG projects would gasify an additional 11 million tonnes per annum and assuming that their power generating output was proportional to that at Kincardine, the additional generation that could be supported at these sites would be an additional 3.3GW.

It was assumed that each of these plants would also have an on-site workforce of 50 people once fully operational.

Table 7-2: UK UCG Power Generation Assumptions

	Assumption
Total additional capacity	3.3 GW
Direct employment per power plant	50

Source: Biggar Economics

In total there are currently eight initial potential UCG sites around the UK. The economic impact associated with power generation potential of these sites was estimated by multiplying the Kincardine UCG power plant by eight (it was assumed that the direct employment at each plant would be similar).

As with the Kincardine UCG plant, the supply chain impact during the operational stage has already been discussed elsewhere in this report, however it was necessary to add the induced impacts of the staff expenditure to the direct impact. This was done using the same approach described above.

In this way it can be estimated that the construction of the new power stations that would be required to make use of the syngas that could be produced at sites around the UK could support 3,988 jobs and generate £1.2 billion GVA. Once these plants were fully operational they could support 573 permanent jobs and generate £40.7 million GVA/year for the UK economy. These impacts are summarised in Table 7-3.

Table 7-3: Summary Power Generation Impact - Total UK UCG Power Plants (3.3 GW)

	Construction		Operational (Annual)	
	Jobs	GVA	Jobs	GVA
UK	3,988	£1.2 bn	573	£40.7m

Source: BiGGAR Economics

7.5 Reducing UK Dependence on Imported Fuel

The UK does not produce enough natural gas to meet its demand and therefore has to import gas from other countries, with natural gas being piped in from the Netherlands and Norway and LNG shipped in from Russia and the Middle East. In 2014 the UK used 18.5 million tonnes equivalent (Mte) of gas in the production of electricity¹⁵. Of this approximately 58% was generated from imported gas. Any reduction in imports as a result of increased domestic gas production will therefore also have a positive impact on the UK's balance of payments.

¹⁵ DECC, Energy Trends June 2015, June 2015

8 SUMMARY

This chapter summarises the impacts considered in this report. These impacts include:

- the direct and indirect impacts associated with the development and operation of an initial UCG project at Kincardine;
- the direct and indirect impacts that could be generated by seven other potential UCG projects elsewhere in the UK;
- the impacts that could be generated if the deployment of UCG in the UK enables companies in the UK to secure a share of the global UCG supply chain; and
- impacts associated with the end use of syngas, in particular as a fuel for power generation and a feedstock for the Scottish chemicals industry.

The starting point for this report was to consider the potential economic impact of Cluff Natural Resources' plans to develop a UCG project at Kincardine. It found that over the long term this project alone could contribute around £603 million GVA to the UK economy, more than a third of which could be retained within the immediate local area.

It was estimated that economic activity associated with this project might peak at around year three of operations at which time the project could be supporting more than 830 jobs across the UK. It is anticipated that activity might level toward the middle of the first decade of operations and that average employment across the UK over the long term could be around 350 jobs.

It is anticipated that the Kincardine project could act as a demonstrator for UCG technology and help to stimulate investment in similar projects elsewhere in the UK. Over the long term it was estimated that other UK UCG projects could generate £5.6 billion GVA for the UK economy and support an average of 3,300 jobs. It was estimated that over 40% of this impact could be retained in Scotland and that almost £0.7 billion GVA and more than 291 jobs could be created in the Firth of Forth area.

As the sector matures it is reasonable to expect that UK based companies will develop specialist experience in UCG technology, which could be exported to other countries with UCG potential. It was estimated that in 30 years time UK based companies could be exporting almost £560 million worth of UCG related exports. Over the long term, sales of these goods and services could generate £6.6 billion GVA for the UK economy and support an average of around 3,300 jobs.

Taken together it is estimated that over the long term a new UK based UCG sector has the potential to generate £12.8 billion GVA for the UK economy and support an average of over 7,500 jobs. It is estimated that around 45% of this impact could be retained in Scotland, including £1.7 billion GVA and an average of around 730 jobs in the Firth of Forth. These impacts are summarised in Table 8-1.

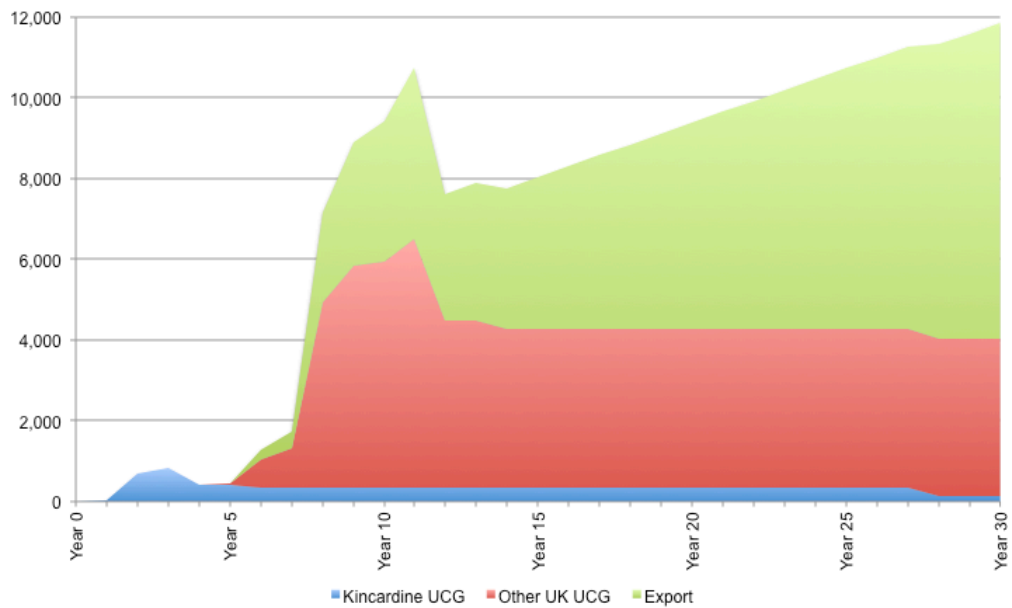
Table 8-1: Summary Quantifiable Benefits

Study area	Total GVA (£m over 30 yrs)	Peak annual GVA (£m)*	Peak employment (jobs)*	Average employment (jobs)
Kincardine Project				
Firth of Forth	230.8	17.6	263	102
Scotland	428.6	33.9	572	240
UK	602.7	48.1	833	354
Other Potential UK UCG Projects				
Firth of Forth	658.9	38.4	543	291
Scotland	2,449.4	145.5	2,442	1,368
UK	5,590.4	350.9	6,143	3,276
UCG Export Potential				
Firth of Forth	773.8	51.8	674	338
Scotland	2,867.6	191.6	3,227	1,607
UK	6,584.9	440.3	7,820	3,881
Total UK UCG Sector Potential				
Firth of Forth	1,663.4	80.8	1,051	731
Scotland	5,745.6	292.9	4,935	3,215
UK	12,778.1	668.4	11,869	7,510

Source: BiGGAR Economics (totals may not sum due to rounding). *totals for these columns do not sum because peak activity for the different parts of the sector will be achieved at different times.

Figure 8-1 depicts how a UK UCG sector might evolve over time. It shows how initial investment in the Kincardine project (shown in blue) could stimulate investment in other UCG projects elsewhere in the UK (shown in red) and how this could result in a significant ramp up in employment in the sector from around year five of operations. It also shows how the experience gained by UK based companies from the development of the Kincardine project and other UK sites could provide the basis for a successful exports sector (shown in green)

Figure 8-1: Employment impacts over time by source



Source: BiGGAR Economics

In addition to the economic impact associated with the UCG sector itself, this report has also considered the potential impacts associated with the use of syngas, the product of the UCG process. There are likely to be two main end uses for syngas; as a fuel for power generation and as a feedstock for the chemicals sector.

It found that taken together the potential UCG projects around the UK could have the capacity to produce enough fuel to power stations with a total capacity of around 3,600 MW. It was estimated that constructing these power stations could generate £1.2 billion GVA for the UK economy and support around 4,000 temporary construction jobs. Once fully operational the power stations could support around 570 permanent jobs and generate a further £203 million GVA/year for the UK economy.

Alternatively syngas could be used to provide a feedstock for the chemicals sector. If used in this way UCG could play a fundamental role in safeguarding 4,800 jobs reliant on the Scottish chemicals sector. This represents an economic contribution to the Scottish economy of between £307 million and £732 million GVA/year.