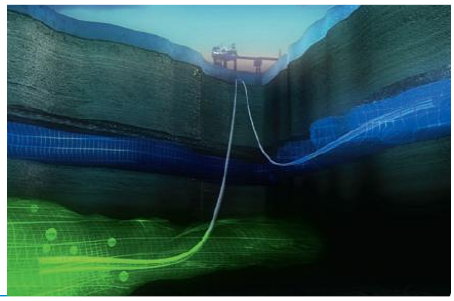


Title: Carbon Capture and Storage Skills Study

Authors: Alan Young, Richard Catterson and Mike Farley

Date: 29th September 2010

Industrial and Power Association
energy. environment. employment.

CONTENTS

1 – Executive Summary

Doosan Babcock, in conjunction with the IPA (Industrial and Power Association) has conducted an assessment of the economic benefits, employment possibilities and skills needs arising from a major global programme of Carbon Capture and Storage (CCS).

A ”bottom-up” assessment based on a single full chain CCS project (a 400MWe supercritical coal-fired power plant with post-combustion carbon capture, pipeline transport and storage in a depleted hydrocarbon field offshore) has been combined with a roll-out programme through to 2050. The rollout Programme is based on the IEA projections for CCS to meet climate change targets and an assumption, judged realistic, that the UK industry will achieve a 10% market share of the global carbon capture market.

The assessment concludes:

- The UK plc share of global business is potentially worth more than £10 -14 Bn/yr from around 2025, with the added value in the UK worth between £5 Bn and £9.5 Bn/yr
- The UK share of this global business could potentially create 27,000 jobs in the UK from 2020 (13,000 of which in Scotland), increasing to 70,000 by 2035 (23,000 of which in Scotland. A further 10,000 jobs, half of which in Scotland, are possible given the right level of government support

The model lists job numbers by engineering profession (by discipline) and craft. It is recommended that these numbers be assessed against the normal output from the education system to ascertain the additional skills required for the CCS Rollout Programme.

Specialist training needs for Power Plant and CCS are identified, including 2,000 new apprentices/year (across the UK), Specialised post graduate – full one year MSc, MSc Power Plant Engineering (Carbon Capture module(s)) MSc CCS, new Specialist MSc level modules in Capture, Transport, Storage (offshore engineering), Storage (geology).

Gaining the maximum benefit depends on UK/Scottish companies winning domestic *and* export projects and government establishing a steady roll out programme. The next steps should include a review with government and its agencies of what actions are needed to maximise economic benefit.

It is clear that the economic opportunities will be delayed if the rollout programme is less rapid than forecast by the IEA, and so will be the climate benefits.

The economic opportunities and jobs in the UK are critically dependent on the UK’s demonstration programme of four projects and UK companies winning a sizeable share of the early Demonstration projects.

2 – Introduction

The Carbon Capture and Storage (CCS) Skills Study was compiled to qualify the considerable economic opportunity of CCS for "UK plc" at home and on a global basis.

The report begins by introducing the concept of Carbon Capture and Storage and UK/Scotland's existing high level of involvement and strong capabilities in the sector. Secondly, the methodology of the Skills Study is explained and then followed by the results of the investigation. Finally, the conclusions and recommendations derived from the analysis will be presented.

The term "UK/Scotland" is used as the figures calculated in the Skills Study are not specific to Scotland but incorporate opportunities for UK industry as a whole. Scottish industry and Universities are well placed to secure a large share of these opportunities.

The Skills Study was completed by Doosan Babcock in conjunction with the IPA, on behalf of

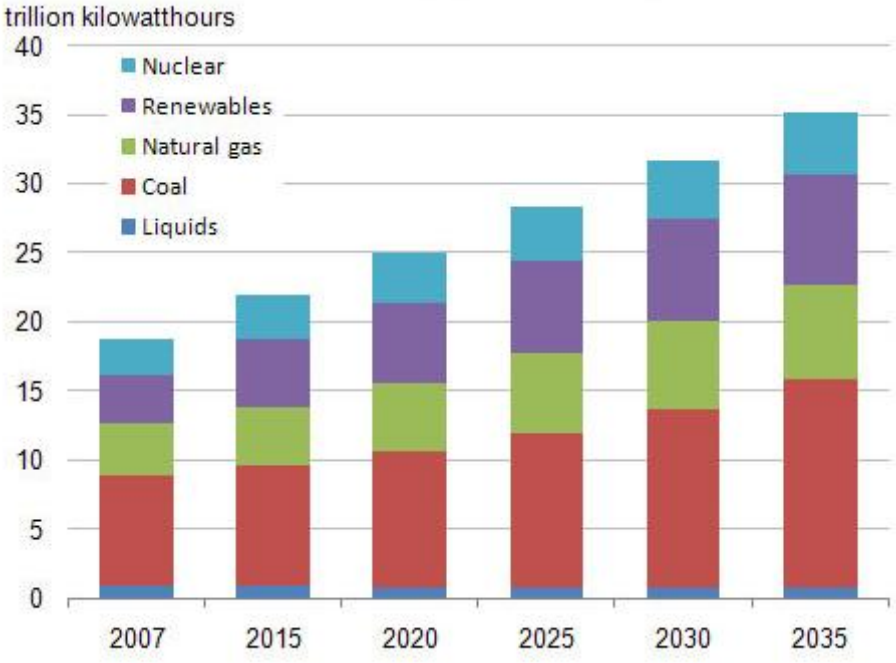
- Skills Development Scotland, who funded the project
- The Scottish Government/Scottish Enterprise IAG (Industrial Advisory Group) on CCS and Thermal Generation
- Scottish CCTS Development Study Work Group 4
- Industrial and Power Association

The authors acknowledge the valuable input, data and comment from members of the above groups.

3 – Carbon Capture and Storage (CCS)

The generation of electricity through burning fossil fuels (coal and gas) results in the emission of carbon dioxide into the atmosphere. Globally the burning of fossil fuels will continue to increase driven by continued growth in Asia and South America. This is demonstrated in the Figure 1 below which shows the world net electricity generation by fuel type;

Figure 1. World net Electricity Generation by Fuel



Taken from: US Energy Information Administration

As can be seen in the chart above, both coal and natural gas will nearly double their generation by 2035 (coal and natural gas combined in 2007 is 12 trillion KWh and in 2035 is 22 trillion KWh) and play an *increasingly* important role in the fuel mix. This highlights the growing importance CCS will have in global energy generation.

CCS is the process of capturing CO_2 produced from the burning of fossil fuels, transporting the CO_2 to a chosen site and storing it deep underground so that the CO_2 that would have been otherwise emitted is not released into the atmosphere. The IEA have identified CCS as one of the key technologies, alongside nuclear and renewables essential to the reduction and stabilisation of CO_2 in the atmosphere.

Coal fired power stations are seen as a prime candidate for Carbon Capture and Storage (CCS) as they emit the highest level of CO_2 per MWh. However, it should be kept in mind that gas fired power plants will also require CCS to meet climate targets as the number of of CCGT plants continues to rise. This is recognised and discussed later in the report.

3.1 Current Industrial Activities in UK for Electricity Generation with Carbon Capture and Storage

The UK has a solid base of knowledge and experience in Carbon Capture and Storage which provides an excellent foundation to build upon in order to take first mover advantage of the CCS opportunities in the UK and worldwide.

Below is a summary of the existing UK CCS knowledge and experience, much of which is based in Scotland;

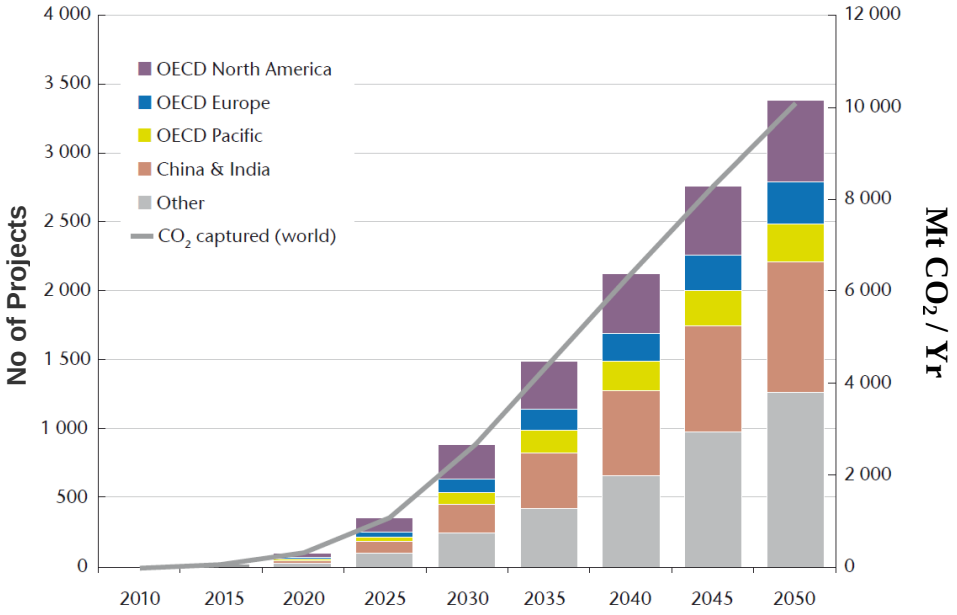
- Capture Pilots
  - SP Longannet Mobile Test Unit
  - Scottish & Southern Energy / Vattenfall / Doosan Babcock Ferrybridge CCPilot100+
- Demonstration of CCS
  - SP, Longannet proposal for UK competition
  - Doosan Babcock - Basin Electric project for US DOE
  - Jacobs - Hatfield FEED study
  - Scottish & Southern Energy – Peterhead study
- R+D on Capture
  - SP, Scottish & Southern Energy , Doosan Babcock, University of Edinburgh, University of Aberdeen
  - Doosan Babcock / Scottish & Southern Energy / SP OxyCoal 40 MW demonstration
- R+D + studies on Storage
  - University of Edinburgh and circa 20 companies, CASSEM
- Power plant
  - Doosan Babcock, Wood Group, Aggreko
- Power plant components
  - Clyde, Howdens, Weir
- Engineering/ Consultancy (incl CCS)
  - Mott Macdonald, Halcrow, Atkins, Jacobs, Foster Wheeler

3.2 Global Carbon Capture and Storage Deployment

The IEA considers that, alongside renewables and nuclear power, CCS is an integral part of the balanced portfolio required to meet global emissions reduction and climate change targets at the lowest possible cost. IEA has forecast the growth programme required for CCS uptake required to stabilise concentration of CO_2 in the atmosphere at 450ppm which translates into 3000 projects globally by 2050. There are around 80 projects under development globally.

As can be seen in the chart below (Figure 2), the number of CCS projects needs to climb steadily up to around 400 projects in 2025 and then make a steep increase to reach more than 3,000 CCS projects by 2050 in order to meet climate change targets.

Figure 2. IEA CCS Project Forecast



Taken from IEA Clean Coal Centre

The IEA forecast serves to highlight the scale of the CCS opportunity, not just in the UK and Europe, but globally.

3.3 Global Opportunities for UK/Scottish Companies

As highlighted in the IEA CCS Project Forecast (Figure 2) it is expected that Europe, including the UK, will have a large number of CCS projects (~500 projects by 2050). Additionally the CCS programme offers UK companies the opportunity to export their products and skills globally. The scale of this opportunity is huge and based on experience in offshore oil and gas and power plant exports it would be realistic to target a 10% global market share or more.

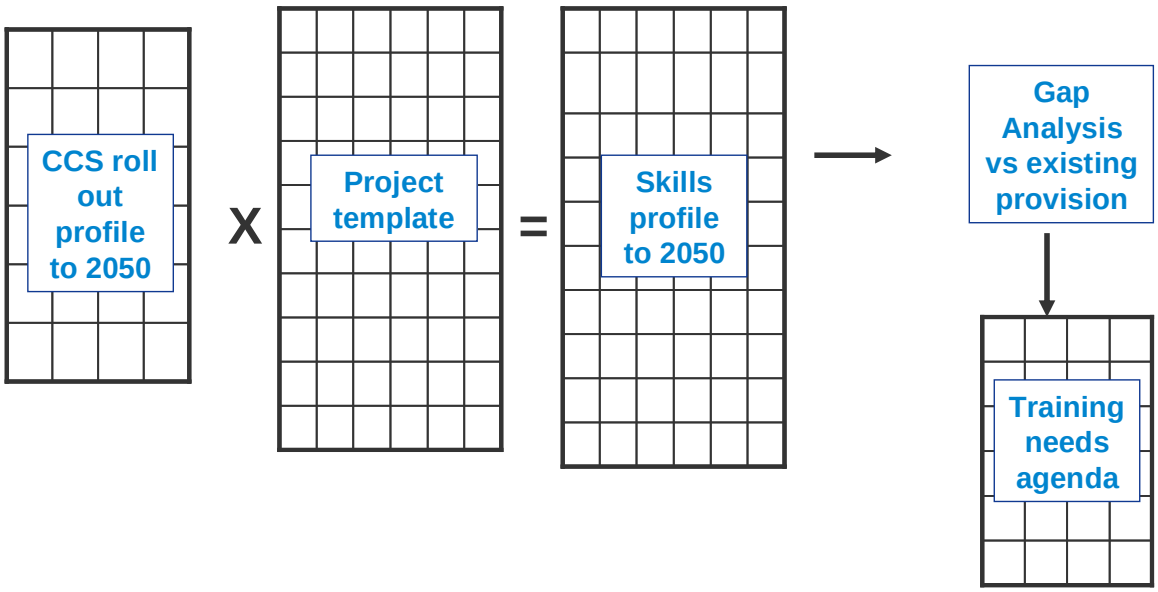
A market share of 10% is used as a basis for the study which is designed to estimate the scale of opportunity (economic and employment) and skills needs.

4 – Skills Study

4.1 Overview of methodology

A ”bottom-up” assessment of a single project (a 400MWe supercritical coal-fired power plant with post-combustion carbon capture, pipeline transport and storage in a depleted hydrocarbon field offshore Scotland) has been combined with a “roll-out programme“ through to 2050, based on the IEA projections for CCS to meet climate change targets and the assumption that UK industry will achieve a 10% share of the global market for power plant with CCS, as indicated below (Figure3):

Figure 3. Methodology Overview



4.2 CCS Rollout Programme

“Roll-out Programmes” have been developed based on the needs of the UK and on the IEA forecast scenario for overseas (see Figure 2). The numbers of projects that might be won by UK companies and organisations which have centred their CCS business here in the UK (collectively referred to as “UK plc”) have been estimated:

- A - Projects won by “UK plc” in the UK
- B - Projects won by “UK plc” overseas

In both cases the economic benefits of the projects are gained by the “UK plc” company/organisation, which could in practice be a subsidiary of a global company (e.g. Scottish Power, Doosan Babcock).

The three phases of the Rollout Programme are split as follows (Figure 4).

- Phase 1 - the early Demonstration projects starting 2011 to 2013
- Phase 2 - the “second tranche” required by 2020
- Phase 3 - the “commercialisation“ post 2020

For projects occurring in the UK it is assumed UK plc will secure all key contracts while for overseas projects UK plc will achieve a 10% share of the global market. The figures and table below (Figures 4 and 5) summarise and total the number of CCS projects by Phase and by Region.

Figure 4. UK share of CCS Rollout

A. UK CCS Rollout

B. Global CCS Rollout

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Figure 5. Total Number of CCS Projects by Phase and Region

	UK	Global	Total by Phase
Phase 1 (2011-13)	4	2	6
Phase 2 (2014-17)	10	8	18
Phase 3 (2018-50)	120	250	368
Total by Region	134	260	392

As can be seen from the data, across the three phases the UK could win a total of 134 CCS projects[1] in the UK and 260 of the Global CCS projects. Progressing through the Phases, the number of projects increases which serves to highlight the scale of opportunity open if, as the government wishes, the UK becomes involved early and progresses to be a Centre of Excellence and a global leader in CCS.

[1] Each project in this model is 400MWe, so 134 projects equals about 50GW, not unrealistic in 2050 when the total installed decarbonised capacity may need to be 200GW. The model assumes each project will be coal–fired. The projected economic benefit and jobs would be reduced commensurate with the share between coal and gas, since the carbon dioxide/MWH is roughly halved.

4.3 Project template

Utilising data from key players in the power, capture and storage industries, including Doosan Babcock, Skoda, Howden, Scottish Power and Shell, the Project template model was developed in nine main work packages (Appendix D) from initial project development to project operations as follows:

- Project development and feed study
- Project Implementation
- Civils
- Turbine and Generator
- Carbon Capture
- CO_2 Transport
- CO_2 Storage
- Operations

In collaboration with the supply chain, all of the individual software and hardware costs, which make up each work package, were assessed and a costing (£) developed for each line item.

Each line item in the model was then assessed on its percentage level of manpower and materials content. The manpower cost of each task was then calculated based on the hourly rate for the direct labour[2] carrying out the task on each. Man-years were then further broken down into the level of input required by each profession (by degree subject) and craft to complete the task.

The resulting labour estimates (man-years) were assigned to the relevant year of the six year build programme (see Figure 3 below).

Figure 6. Example of Manpower Cost Breakdown

400MW PF plant + Capture plant + Transport + Storage	Category	% of Jobs in Crafts	% of Jobs in Mechanical Engineering	% of Jobs in Civils Engineering	% of Jobs in Electrical Engineering	% of Jobs in Process Engineering	% of Jobs in Offshore Engineering	% of Jobs in Geology	% of Other Jobs	Headline Capex	% Labour Content	Total Labour Cost	Manhours (if applicable)	Averaged Rate/Hr	Manyears for 400MW project (if applicable)	Y1 Project development	Y2 Enginnering	Y3 Y4 Procurement and Manufacturing	Y5 Y6 Commissioning and Construction	ongoing Operation	UK/Scotland Possibly UK/Scotland Non UK/Scotland
Project development and FEED study	Overall Feed Study		20%	10%	10%	20%	20%	20%	0%	£ 10,000,000	100%	£10m	200,000	50	113	113					UK/Scotland
	Total >>>									£ 10,000,000											

It was then considered if the project will lead to added value and employment in the UK. The calculated jobs were assessed for their likely location and ascribed to three categories:

- Likely jobs in UK – includes design, engineering, project management, and for UK projects only construction and operations

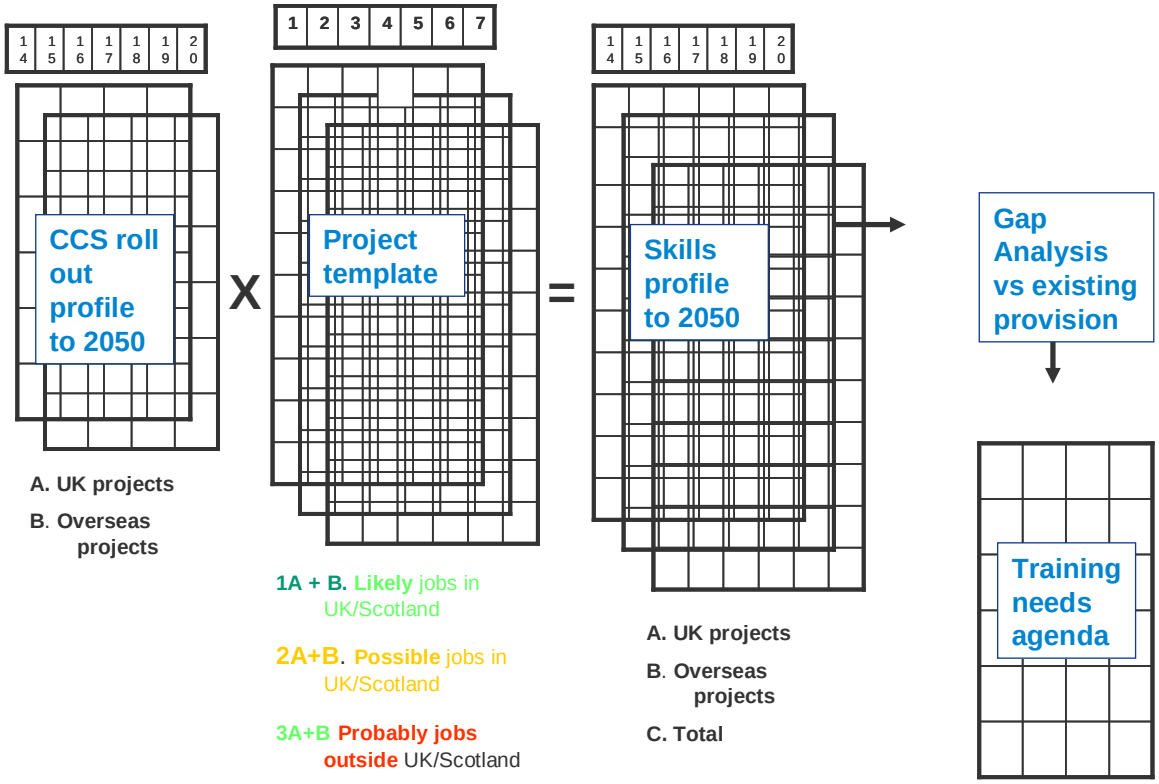
[2] The labour rates used are those charged for direct labour and are inclusive of both pay and overheads. As a result the Jobs calculated are just the "Direct" specialist job and do NOT include the ancillary overhead jobs associated. These are additional to the jobs figures calculated.

- Possible jobs in UK – includes manufacture of plant and equipment that might otherwise be imported
- Probably jobs outside UK – includes overseas construction and operations and imported materials

5 – Skills Study Results

The completed Project Template was then combined with the 'Roll-out Programme' to calculate the overall the economic opportunity and employment prospects for the UKplc share of the CCS Rollout Programme 2011 – 2050 (as shown in Figure 7 below).

Figure 7. Skills Study Results



All of the results are summarised in graphical representations to show;

- The total expenditure (predominantly CAPEX) by year on the UKplc CCS Projects
- The number of jobs split by the nine work packages identified
- The number of jobs split by the eight job disciplines identified
- The total number of jobs made available by CCS

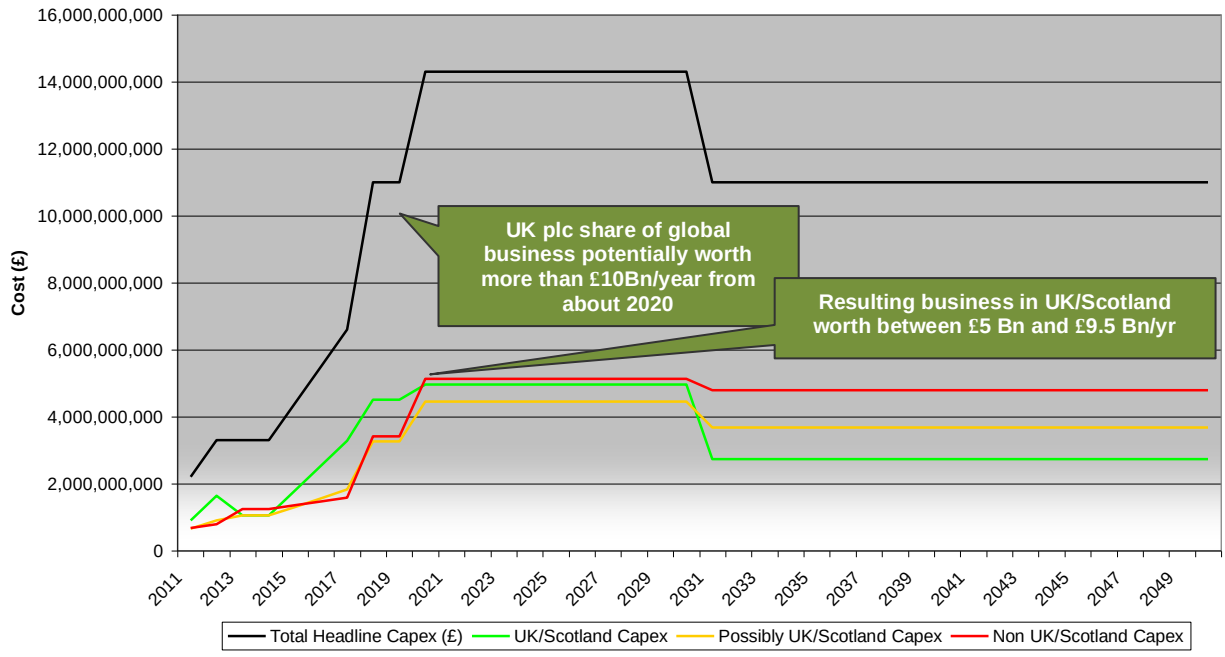
The charts relating to job numbers are split to show figures for

- UK/Scotland
- Possibly UK/Scotland
- Non UK/Scotland

5.1 Headline Capex

The graph below shows the CAPEX required for the CCS Rollout Programme.

Figure 8. CCS CAPEX

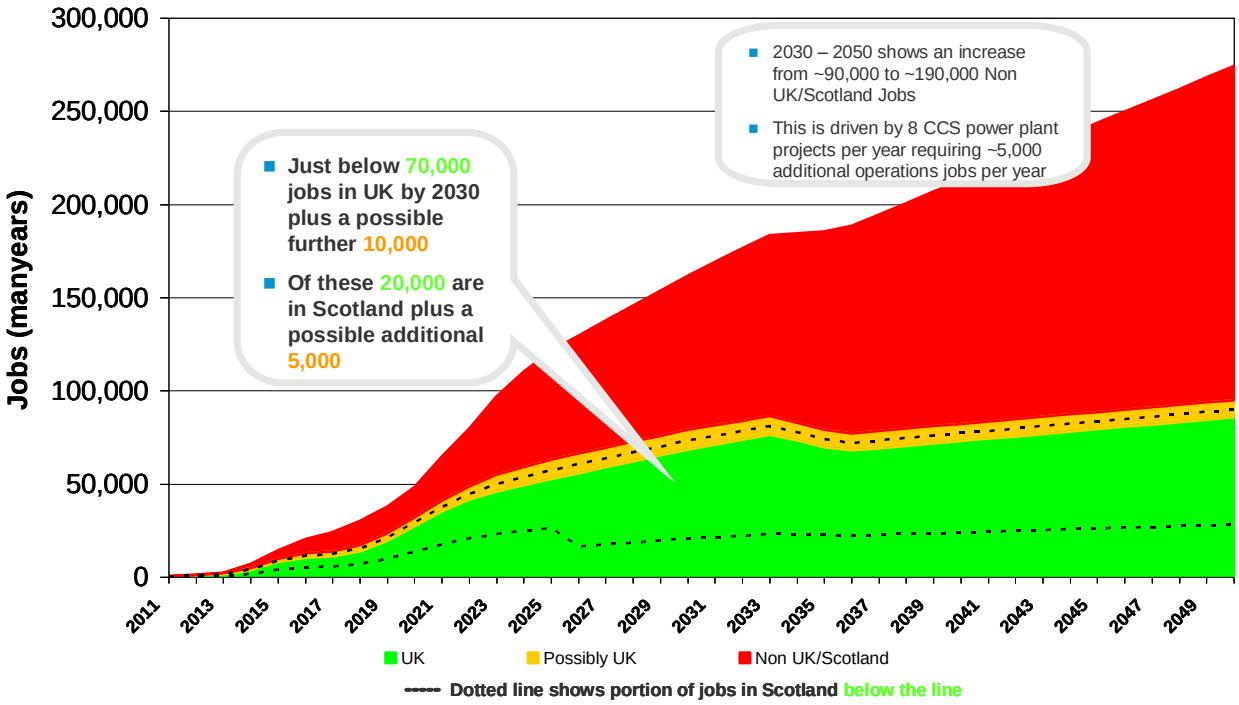


The total headline CCS Capex rises rapidly from 2011 to 2020 to a high of just over £14m investment per annum for ten years as the UK completes its total programme and then continues around £11m investment per year up until 2050. UK/Scotland (excluding possibly UK/Scotland) Capex rises to around £5m per annum in 2020 where it stays until 2030 and then drops down to an average of over £2m up until 2050.

5.2 Total CCS Jobs

The graph below (Figure 9) shows the total potential jobs created by CCS projects.

Figure 9. Total CCS UK Jobs



The figures above highlight the prospects open to the UK, and specifically Scotland, in CCS. The jobs in UK climb steadily from 2011 – 2018 then begin to increase more rapidly year on year reaching 70,000 jobs by 2030, 20,000 of which will be in Scotland. By 2030 there is also a further 10,000 CCS jobs possibly in the UK of which 5,000 will be in Scotland. The increasing trend continues up to 2050 where it is forecast that Scotland could have nearly 30,000 of the 85,000 jobs in the UK plus just under half of the further 9,000 jobs possibly in the UK.

It is important to recognise that the numbers of CCS jobs in UK/Scotland are spread across all of the jobs disciplines and work packages. This is reflected in the full breakdowns in Appendix A. Number of Jobs by Work Package and Appendix B. Number of Jobs by Discipline.

Figure 10 below highlights the breakdown of jobs by Work package in 2030 to further demonstrate the importance of *all* the Work packages if the full economic value is to be realised in UK/Scotland;

Figure 10. 2030 Job Breakdown by Work Package

Work Package	Number of UK Jobs
Project Development and Feed Study	563
Project Implementation	0
Civils	9,860
Boiler	12,409
Turbine and Generator	310
Carbon Capture	7,325
CO_2 Transport	1,605
CO_2 Storage	2,635
Operations	34,307
TOTAL	**69,014**

5.3 Skill Requirements

It is important to identify the skills required to allow UK/Scotland to be a leader in CCS. The table below (Figure 11 Skill Requirements) splits the job disciplines and identifies the number of jobs per year (2011 – 2020) required to meet the CCS rollout programme.

Figure 11. Skill Requirements

Discipline	Number of Jobs pa required each year to meet CCS Programme (additionally)										Additional Training Requirements
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Mechanical Engineering	188	448	477	938	1,503	2,155	2,890	3,700	4,772	6,388	Degree plus post grad training
Civil Engineering	32	72	67	355	878	923	739	1,075	1,640	2,239	Degree
Electrical Engineering	48	98	72	157	213	284	356	485	581	748	Degree plus post grad training
Process Engineering	62	133	113	199	267	347	442	600	717	896	Degree plus post grad training
Offshore Engineering	27	68	68	119	253	447	562	607	792	1,074	Degree plus post grad training
Geology	25	57	50	88	193	350	452	491	633	859	Degree plus post grad training
Crafts	0	0	37	1,624	4,744	5,767	5,492	6,633	10,040	14,487	Modern apprenticeships
TOTALS	382	876	884	3,480	8,051	10,273	10,933	13,591	19,175	26,691	

It is recognised that a number of these jobs will be filled by skilled personnel transferring from other industries (e.g. oil and gas) to take up involvement in the CCS Rollout Programme. However, the *total* workforce required will have to be maintained by newly trained personnel. The training requirements are identified in the table above and UK/Scotland must recognise this early so as to invest in suitable CCS training programmes such as specialised post graduate – full one year MSc, MSc Power Plant Engineering (Carbon Capture module(s)) MSc CCS, new Specialist MSc level modules in Capture, Transport, Storage (offshore engineering), Storage (geology) and meet a demand for 2,000 apprentices/year (across the UK). This will allow UK/Scotland to take advantage of the opportunities presented in Carbon Capture and Storage.

It is recommended that Skills Development Scotland (SDS) assesses these numbers against the normal output from the education system.

5.4 Variations to Estimates

The estimates made in this assessment are clearly sensitive to many inputs:

1. The IEA Roll Out is sometimes considered to be very ambitious, but it is based on “climate needs”
2. The estimate of market share (10%) has been described as ambitious but offshore oil and gas experience suggests a larger share could be possible
3. The estimate of the total number of UK projects with CCS is larger than might have been expected, about 50GW by 2050. However this is not unrealistic in 2050 when the total installed decarbonised electricity capacity may need to be 200GW and around ¼ would need to be fossil fired.
4. The methodology for this study was based upon a single full chain project for a 400MWe supercritical coal-fired power plant with post-combustion carbon capture, pipeline transport and storage in an offshore depleted hydrocarbon field over a six year build programme. The model assumes each project will be coal–fired but it is

important to recognise gas fired power stations with CCS and the effect it would have on the results. This means the projected economic benefit and jobs would be reduced commensurately with the share between coal and gas, since the carbon dioxide/MWH is roughly halved.

6 – Conclusions and Recommendations

The assessment concludes:

- The UK plc share of global business is potentially worth more than £10 – 14Bn/yr from around 2025, with the added value in the UK worth between £5 Bn and £9.5 Bn/yr
- The UK share of this global business could potentially create 27,000 jobs in the UK from 2020 (13,000 of which in Scotland), increasing to 70,000 by 2035 (23,000 of which in Scotland. A further 10,000 jobs, half of which in Scotland, are possible given the right level of government support

The economic opportunities and jobs in the UK are critically dependent on the UK's demonstration programme of four projects and UK companies winning a sizeable share of the early demonstration projects.

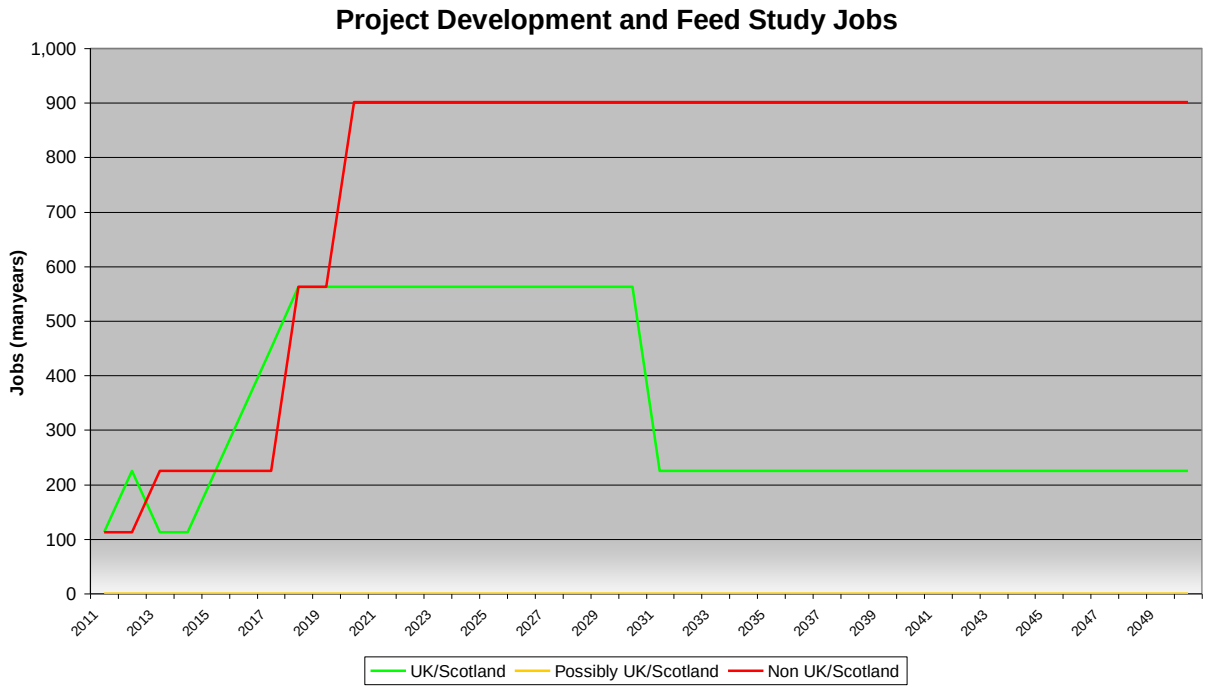
Specialist training needs for Power Plant and CCS are identified, including 2,000 apprentices/year (across the UK), specialised post graduate – full one year MSc, MSc Power Plant Engineering (Carbon Capture module(s)) MSc CCS, new specialist MSc level modules in Capture, Transport and Storage (offshore engineering), Storage (geology).

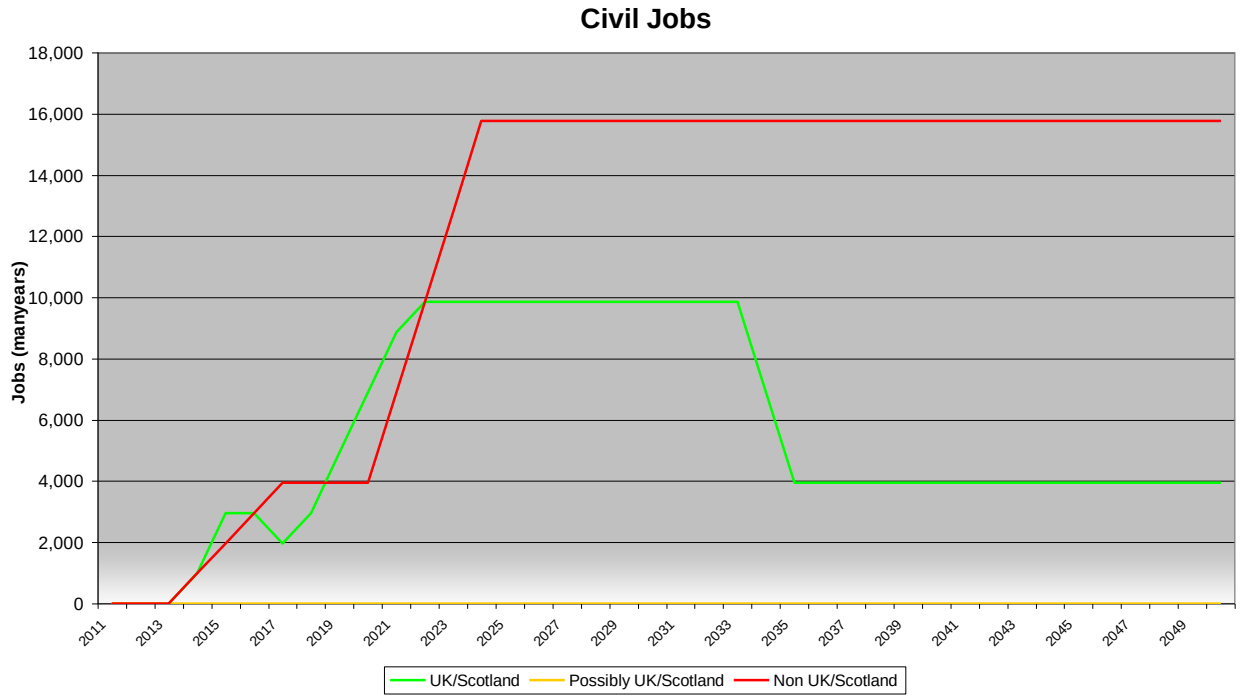
The training needs have to be further analysed and it is recommended that the SDS access the Skill Requirement numbers (see Figure 11) against the normal output from the education system so as to identify additional skill requirements (by engineering profession and discipline) for the CCS Rollout Programme.

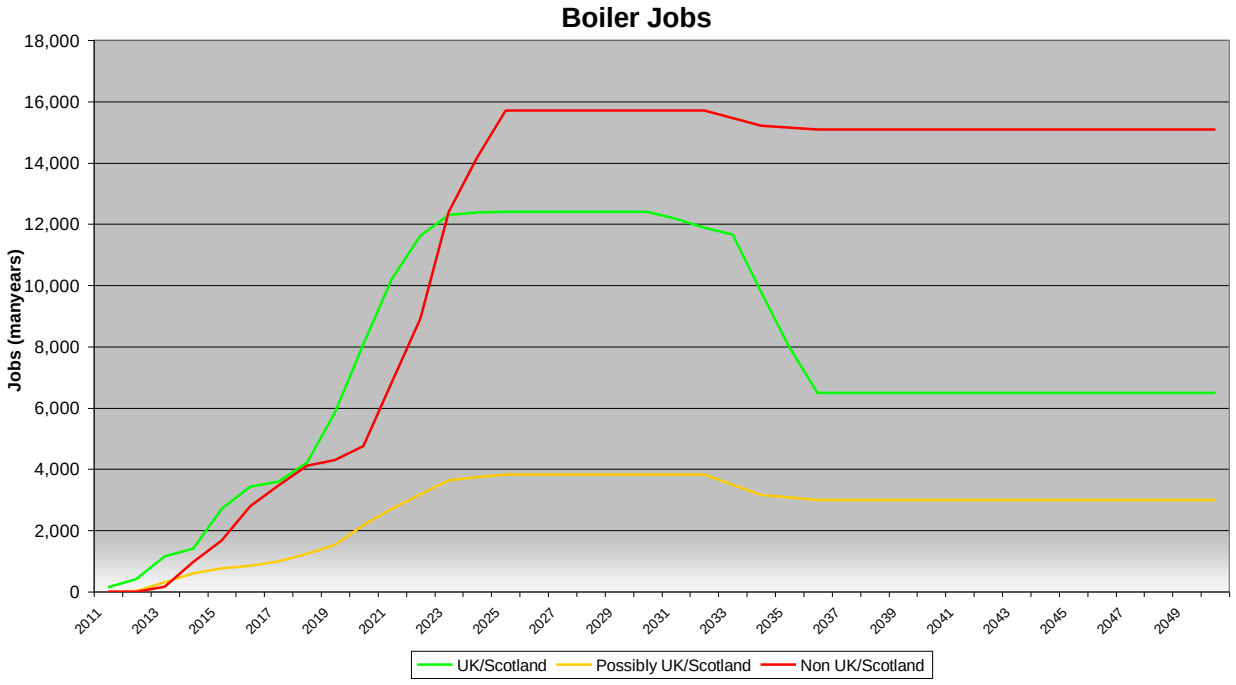
The next steps should also include review with government and its agencies of what actions are needed to maximise the economic benefit.

7 – Appendicies

Appendix A – Number of Jobs by Work Package






Boiler Jobs
Jobs (manyears)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
2011
2013
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033
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2037
2039
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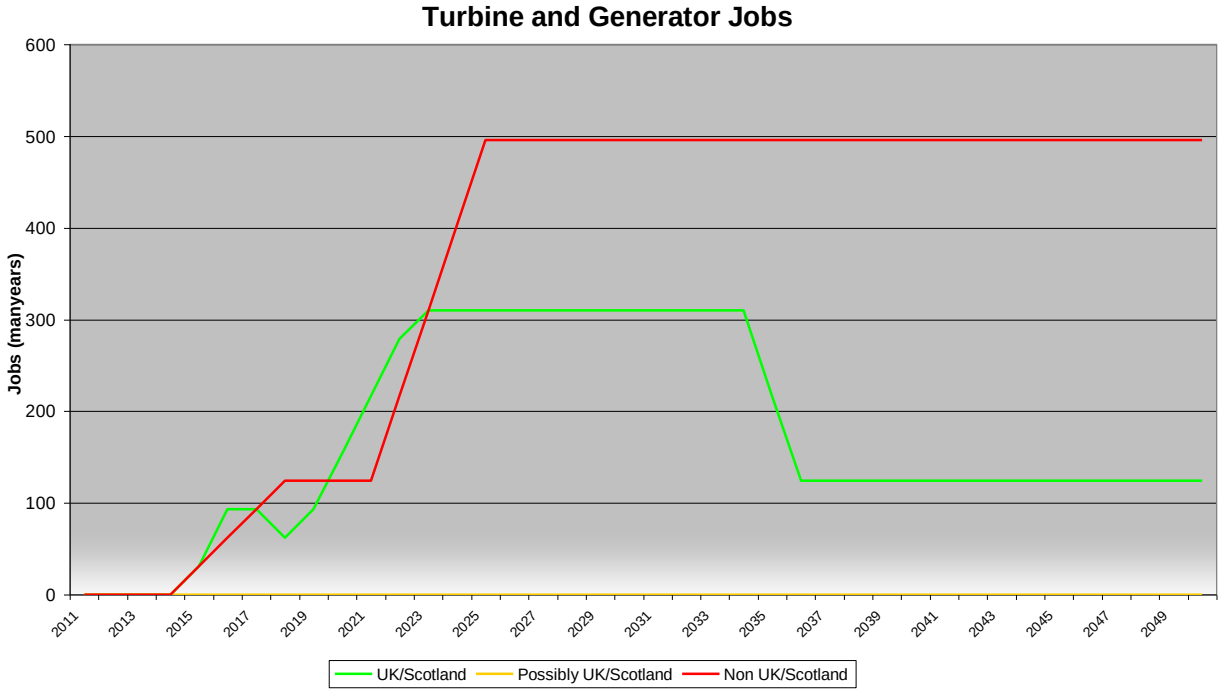
2043
2045
2047
2049
UK/Scotland
Possibly UK/Scotland
Non UK/Scotland


Turbine and Generator Jobs
Jobs (manyears)
600
500
400
300
200
100
0
2011
2013
2015
2017
2019
2021
2023
2025
2027
2029
2031
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2035
2037
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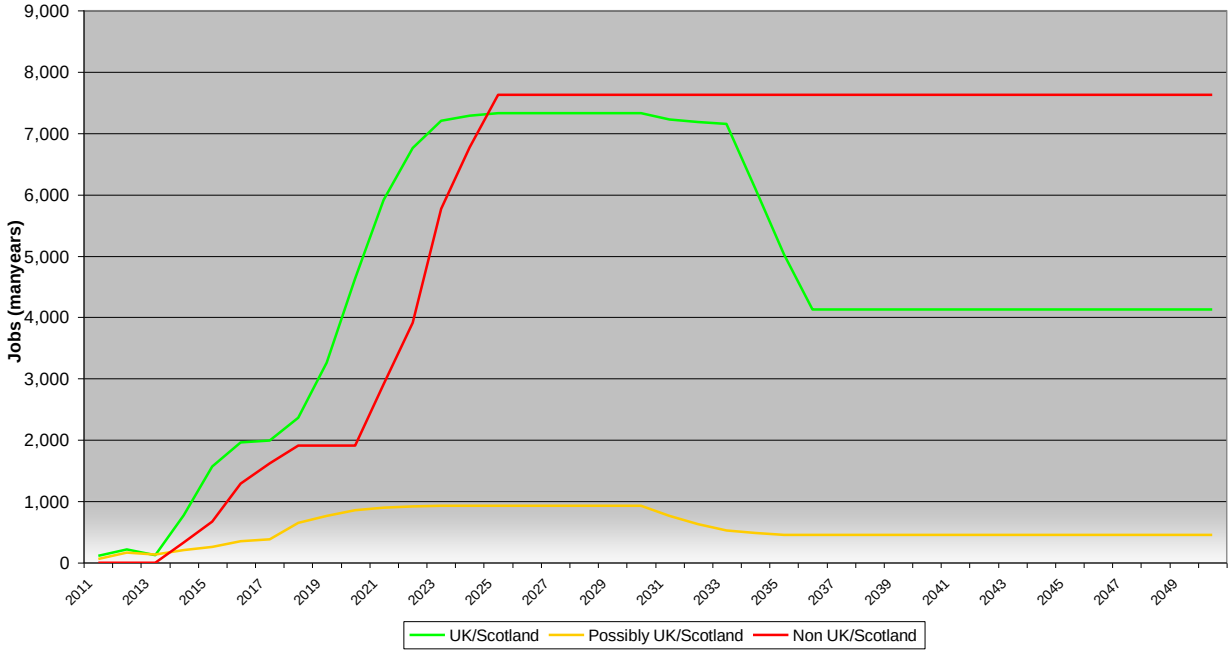
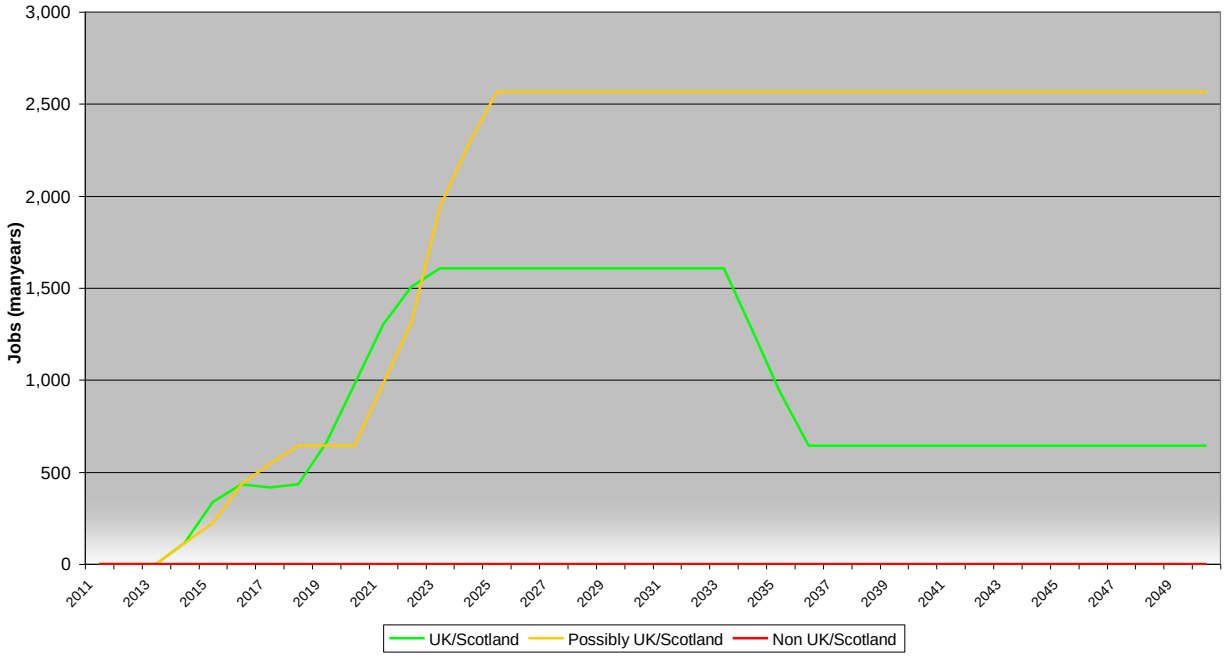
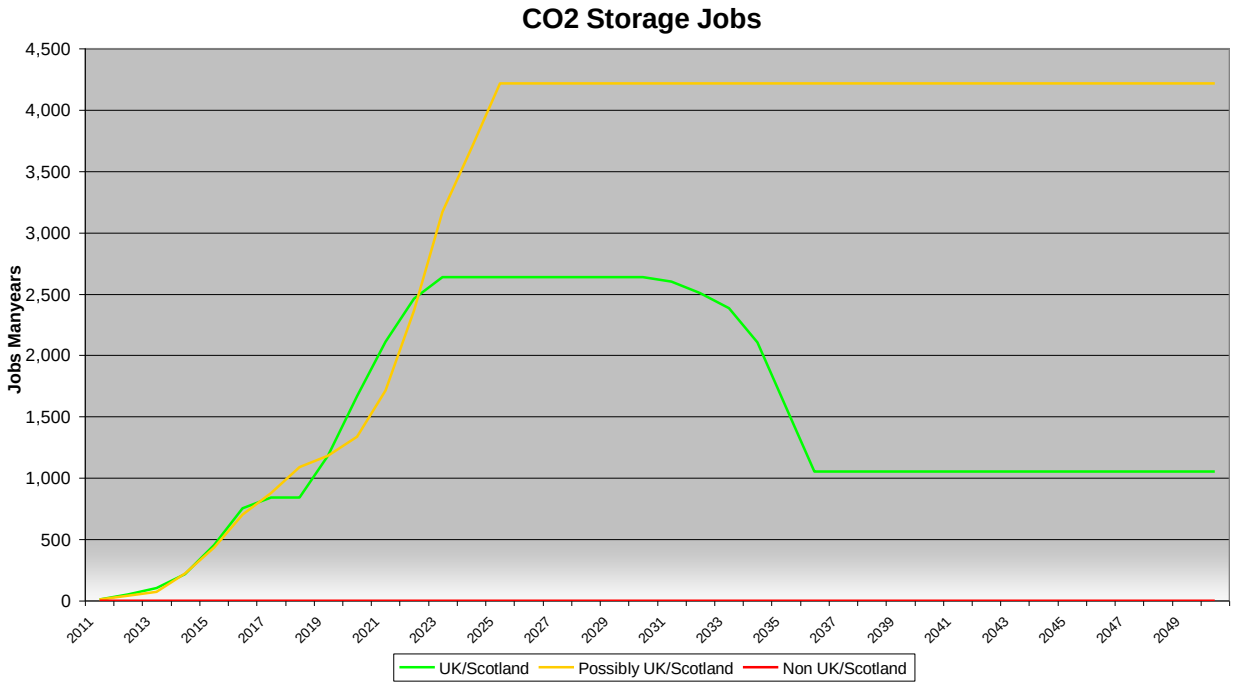
2041
2043
2045
2047
2049
UK/Scotland
Possibly UK/Scotland
Non UK/Scotland

Carbon Capture Jobs



CO2 Transport Jobs




CO2 Storage Jobs
Jobs Manyears
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
2011
2013
2015
2017
2019
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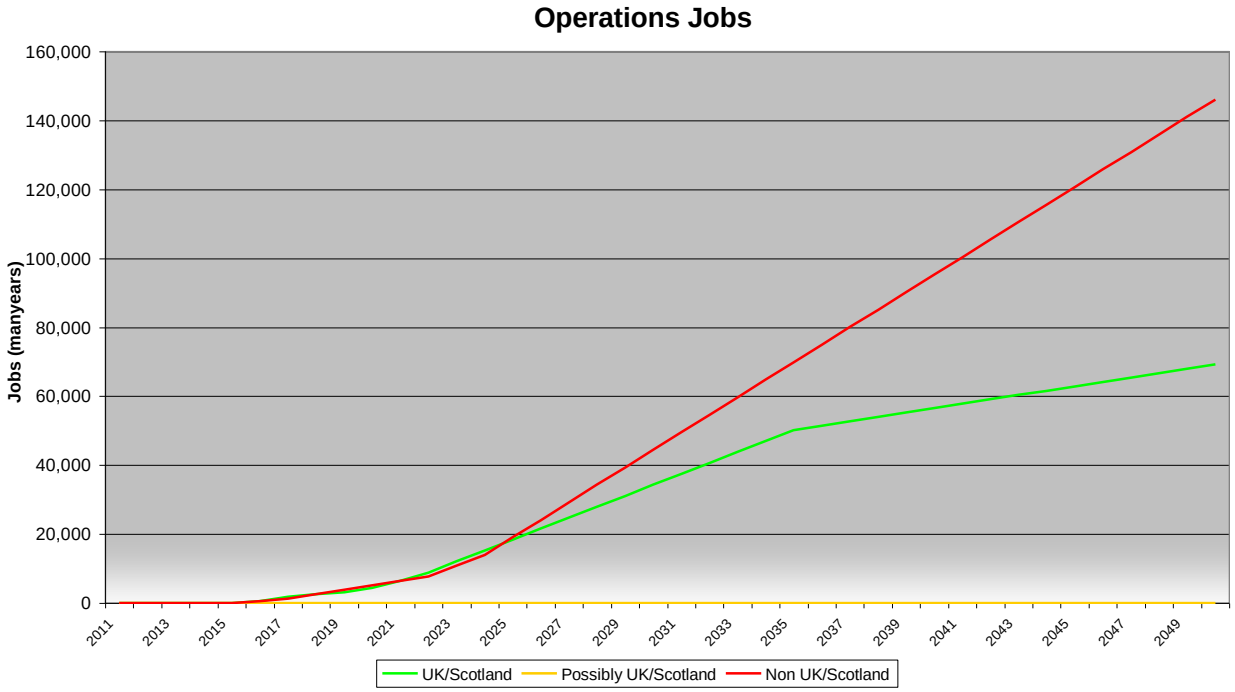
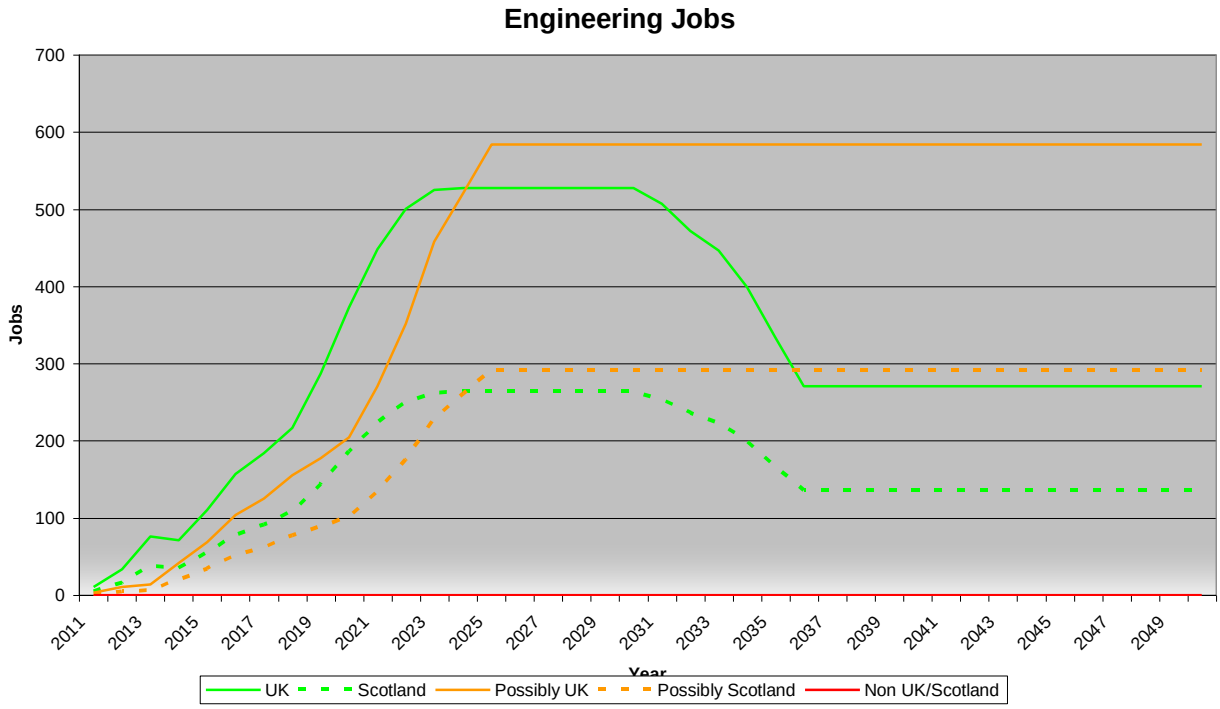
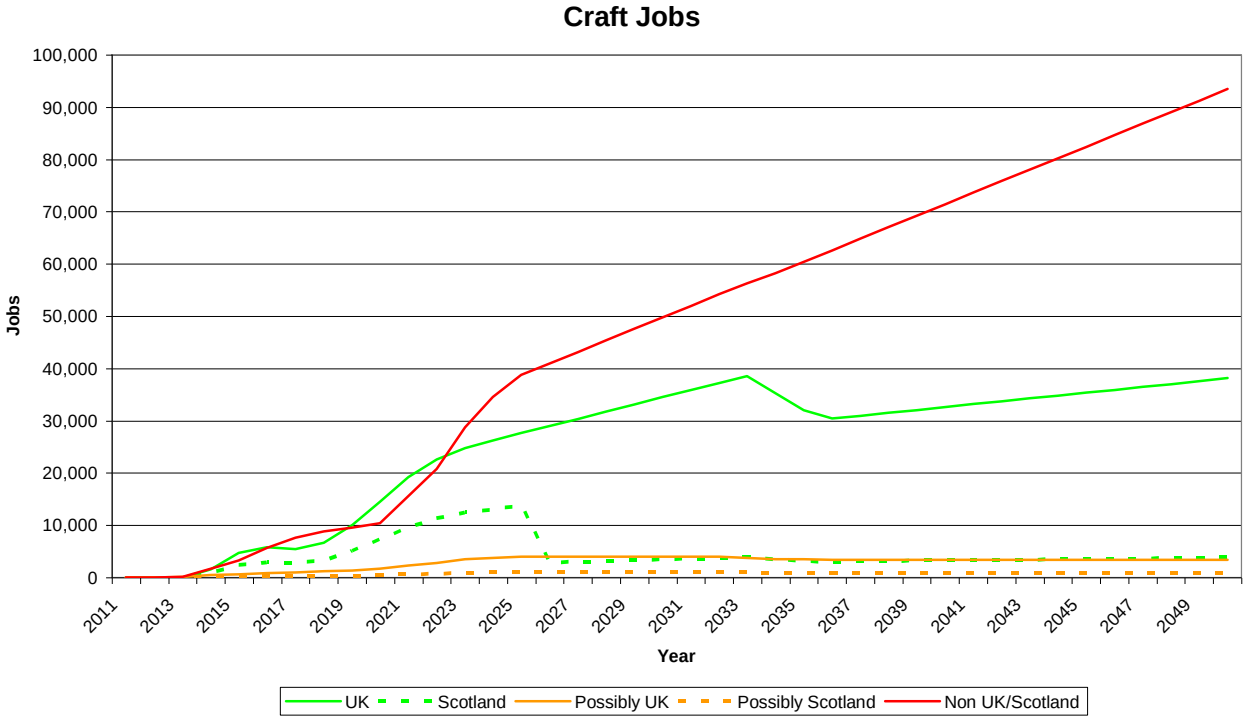

Operations Jobs
Jobs (manyears)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
2011
2013
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
2043
2045
2047
2049
UK/Scotland
Possibly UK/Scotland
Non UK/Scotland

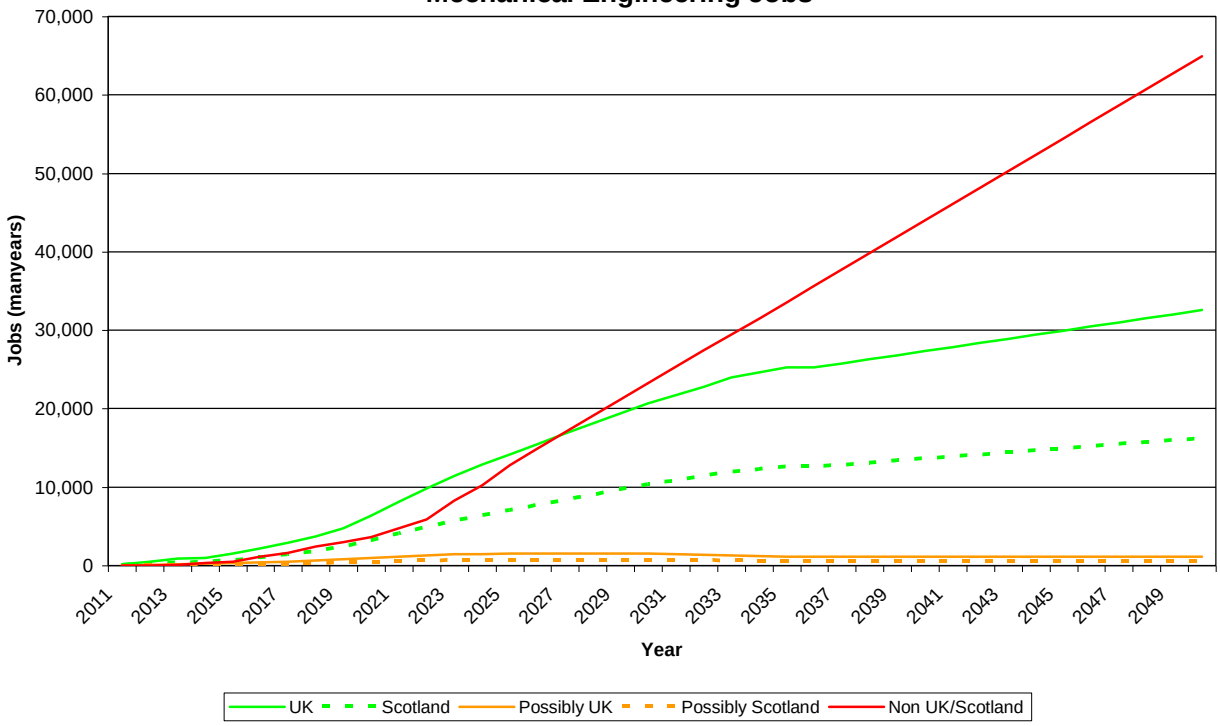
Appendix B – Number of Jobs by Discipline

Note that dotted lines show the amount of jobs for 'UK' and 'Possibly UK' that will be in Scotland





Mechanical Engineering Jobs



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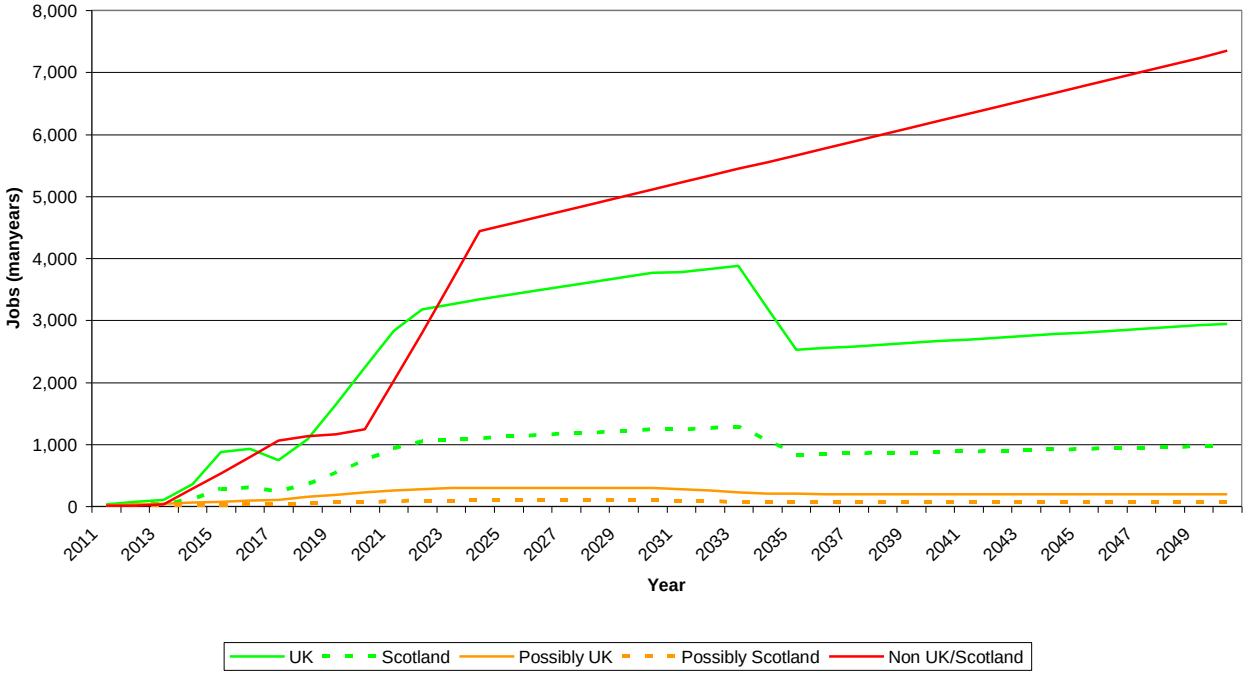
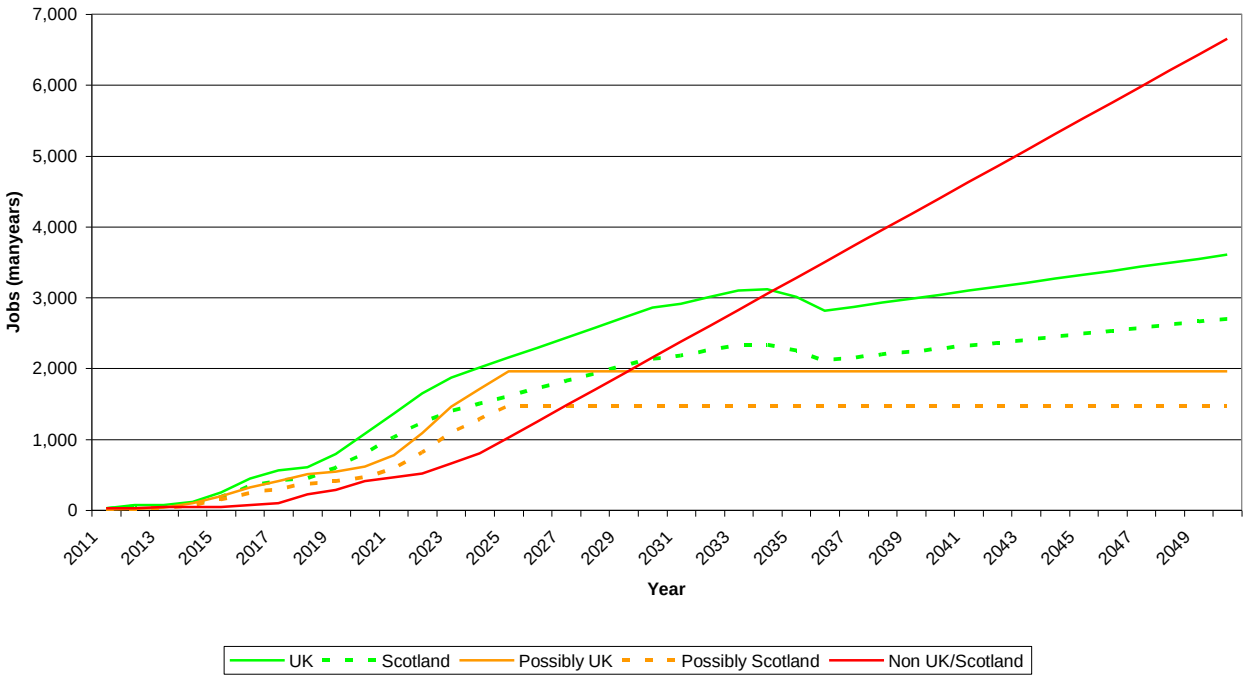


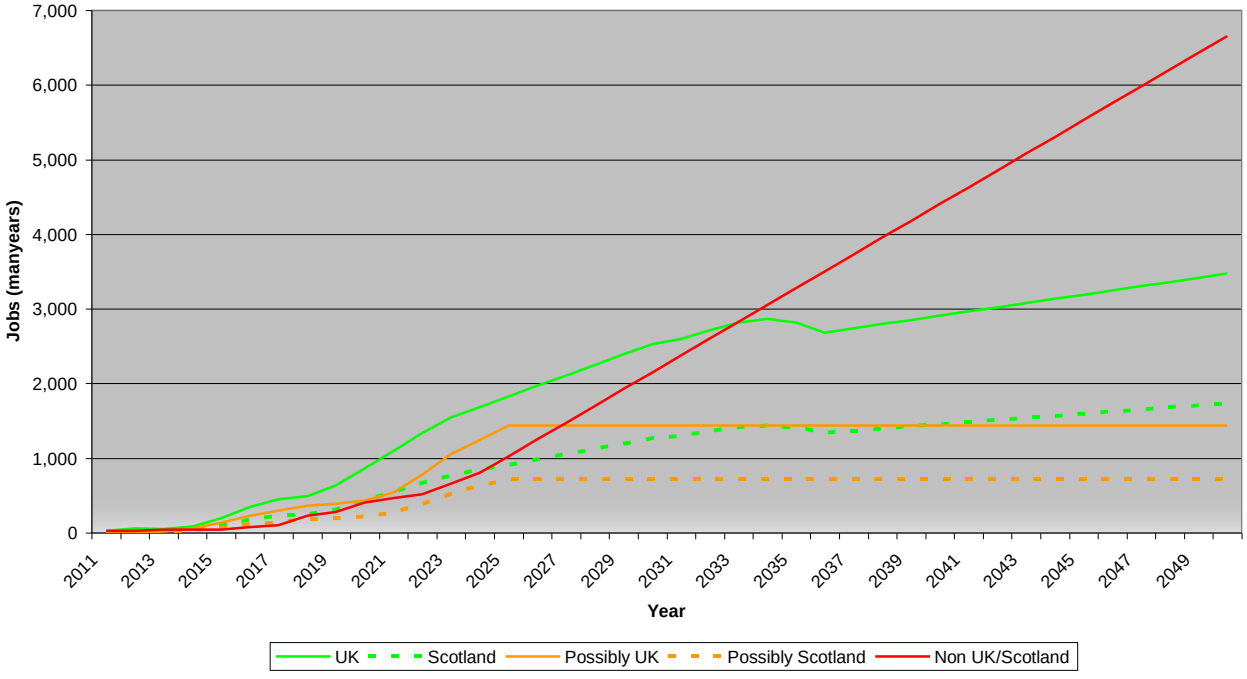
Eletrical Engineering Jobs

Process Engineering Jobs

Offshore Engineering



Geology Jobs



Appendix C – Project Partners

The Carbon Capture and Storage Skills Study was completed by Doosan Babcock in conjunction with the IPA, on behalf of

- Skills Development Scotland, who funded the project
- The Scottish Government/Scottish Enterprise IAG (Industrial Advisory Group) on CCS and Thermal Generation
- Scottish CCTS Development Study Work Group 4
- Industrial and Power Association

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Appendix D – Block Diagram of CCS Process