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ECONOMICS·RESEARCH·ANALYSIS

Socio-economic Impact of Unconventional Gas in Wales

A Final Report by Regeneris Consulting, Cardiff University and AMEC

Welsh Government

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Definitions

Coal bed methane - methane gas which is contained within coal seams as the result of coal formation, either being adsorbed into coal micropores (<2nm) or dispersed in pore spaces surrounding it

Shale gas - natural gas that is trapped within rock shale formations, with a combination of horizontal drilling and fracture technology being required to enable economic extraction of oil or gas

Underground coal gasification - a process by which air, oxygen and steam are injected into coal seams at depth in order to partially combust the coal, producing heat, hydrogen, carbon monoxide and methane and in some seams, sulphur gases

Direct economic impact – the economic activity which arises as a direct consequence of expenditure associated with exploration, extraction and long term production of unconventional gas

Indirect economic impact – the economic activity which arises through the supply chain supporting the exploration, extraction and long term production of economic impact

Induced economic impact – the economic activity which arises through the personal expenditure of workers whose jobs are supported directly or indirectly by unconventional gas extraction

FTE – full time equivalent employment is a measures of economic impact used in the assessment

GVA – Gross Value Added (GVA) is a measure of wealth creation used in the assessment

Input-Output tables - the assessment uses the Input-Output (IO) tables for Wales in order to estimate the direct, indirect and induced GVA and FTE effects of economic activity in Wales.

Executive Summary

Introduction

i. The exploitation of unconventional gas in the UK, covering shale gas and oil, coal bed methane and underground coal gasification, is at an early stage. However, it has been the focus of much interest due to the potential to provide additional security of supply, to enhance the UK's energy mix and to potentially provide a lower cost energy source.

ii. However, there remains considerable uncertainty about the amount of resource and the extent to which this is technically or economically recoverable. Various strategic studies have been commissioned by the UK Government's Department of Energy and Climate Change (DECC) for the UK as a whole and in areas of the UK considered to be most prospective for gas and oil. The Welsh Government commissioned a study on the potential unconventional gas resource in Wales, which concluded that further data on the geology, engineering and associated costs of production is needed to make credible resource and reserve estimates.

iii. It is recognised that the industry has the potential to bring significant economic benefits to the UK and to particular locations. This has focussed on shale gas in particular, with widely differing estimates of the scale of employment supported. At the same time there are concerns about the potential environmental and social impacts of particular technologies and the effect they may have on host communities, and particular sectors (e.g. tourism, intensive gas using sectors).

iv. Given that the industry in Wales is in its infancy, there is an opportunity to consider the potential socio-economic impacts of unconventional gas for Wales. This study aims to make an important contribution to this thinking and inform policy development. Whilst the Welsh Government does not have full devolved responsibility for energy policy, it has various regulatory, policy, fiscal and resourcing mechanisms available to influence the development of the sector in Wales.

Policy

v. Within the UK Government, there is a clearly now a supportive policy environment for the development of unconventional oil and gas, setting out to provide a safe, responsible and environmentally sound basis for the recovery of the unconventional reserves of oil and gas within the UK. The UK Government has committed to exploiting the potential of unconventional gas production, with support for the industry including:

- Undertaking research to demonstrate the extent of unconventional oil and gas reserves within the UK, as well as the economic benefits of the growth of the sector and its supply chain.
- The establishment of the Office for Unconventional Gas and Oil (OUGO) which works with HM Treasury to support the growth of unconventional energy industries by ensuring coherence between the regulatory, licensing and taxation regimes, as well as providing a framework to deliver benefit to local communities that accommodate development.

NOTE

The economic impacts outlined within this work are based on policies in place as of January 2015.

The following changes to policies have occurred between January and June 2015:

- Notification direction from the Minister for Natural Resources to local planning authorities on 13 February requires the referral of applications for unconventional gas and oil that involves unconventional extraction techniques (including hydraulic fracturing) to Welsh Ministers if the local planning authorities are minded to approve them.
- The Infrastructure Act (12 February 2015) contains provisions relating to environmental and planning safeguards for unconventional gas developments.
- On 1 April 2015 certain functions passed from the Department of Energy and Climate Change (DECC) to the Oil and Gas Authority (OGA). OGA is responsible for regulating offshore and onshore oil and gas operations in the UK including oil and gas licensing.
- Powers for a Purpose: Towards a lasting Devolution Settlement for Wales published on 27 February commits the UK Government to devolve to the National Assembly the licensing of onshore oil and gas underlying Wales.
- On 20 April the Minister for Economy Science and Transport issued a Written Statement on Energy, setting out the Welsh Government's vision for energy which is to:
  - safeguard and maximise the Welsh energy position through strong leadership across government;
  - maximise the benefit to Wales of the transition to low carbon generation, for businesses, households and communities;
  - maintain a business friendly, competitive environment for investment and affordable supply, and
  - seek to secure parity and increased influence within the UK , and wider afield, for Wales and Welsh interests.

- Publishing guidance on the regulatory and permitting framework for unconventional oil and gas in order to improve understanding of the framework and procedures (the Regulatory Roadmaps).
- Provision of greater clarity for industry around the long-term tax treatment of shale gas profits by providing a new shale gas field allowance and extending the ring-fence expenditure supplement in order to promote investment.
- Consulting on measures designed to simplify the existing procedure for underground access when seeking to exploit oil, gas or geothermal resources, with resulting amendments proposed to the Infrastructure Bill.
- More generally, working with key stakeholders including industry (through the UK Onshore Operators Group, UKOOG), on issues such as regulation, supply chain development and skills. For example, UKOOG has introduced the Community Engagement Charter in order to ensure that local communities benefit from hosting future oil and gas developments.

vi. Policies surrounding the use of unconventional gas as a source of energy is set at the UK level by the UK Government. However the Welsh Government is responsible for a number of areas which impact on the industry, such as planning policy and environmental regulation.

vii. The Welsh Government is committed to moving towards a low carbon economy and sets out its ambitions for tackling climate change in the Climate Change Strategy for Wales. While meeting these climate change goals, the Welsh Government aims to maximise the benefit to the people of Wales and create wealth and employment in the process. Its approach to unconventional gas is currently precautionary while it considers the evidence and undertakes further research into benefits and disbenefits of unconventional gas in Wales.

Potential Unconventional Resources and Reserves

viii. The UK has substantial unconventional reserves of oil and gas. However, at present neither DECC nor the industry have sufficient engineering, geological or cost information to make a meaningful estimate of overall technically recoverable reserves. Whilst this information will improve as further intrusive exploration is undertaken, it needs to be borne in mind that estimates of technically recoverable reserves have no implication for whether these reserves are economically viable at current prices, or in relation to other economically marginal sources of fuel that may become attractive following a price increase.

ix. Potential unconventional gas resources in Wales are most likely to be found in association with coal seams or shales. The evidence on resources in Wales, which is currently much more extensive for coalbed methanes, points to the following:

- Six wells have been drilled to date and other permissions are in place for exploratory drilling. Based on a 10% recovery factor, BGS suggest a combined resource estimate for CBM in South Wales of between 3 and 6bcm (equivalent to between 4% and 8% of annual UK gas consumption[1]) and between 3 and 9bcm in North Wales (equivalent to between 4% and 11% of annual UK gas consumption)
- Outside the coalfields, there has been very little exploration for unconventional hydrocarbon resources in Wales to date. This has led to a paucity of subsurface data against which to evaluate potential resources of shale gas. BGS concluded that "*there is presently not enough*

[1] DECC (2014) Energy Trends Section 4: Gas, Table 4.1 Natural gas supply and consumption.

publicly-available data available on the geology, engineering or associated costs of production to make reliable estimates at this stage".

Factors Influencing Pace of Development

x. The nature and pace of any future exploration and production of unconventional oil and gas in Wales (and more widely in the UK) will reflect differences in geology, changes in regulatory regimes and varying market conditions. Key considerations are likely to be:

- **Global Economic Factors**. Factors that could increase exploration activity across the UK, including the UK Government's interest in encouraging this activity, could include energy costs/shocks (increasing consumer energy costs and increasing economic viability of onshore exploration and production) and global political pressures affecting energy markets (creating demand for increased energy security through greater use of indigenous resources). However, at this stage, such changes (if or when they are to occur) are highly uncertain. Current low world oil and gas prices may provide a particularly weak stimulus to exploration within the UK, although this is a reflection of both weak global demand and new sources of shale gas in particular coming on stream and is unlikely to persist in the medium to long term.
- **Resource Uncertainties.** Exploration companies can invest regionally/globally and the likelihood that they will focus their effort on exploration for shale gas in Wales is considered limited in the short term given the amount of up-front investment needed to delineate the scale of the resource/reserve and the greater interest in other parts of the UK. However, in the longer term, it is likely that exploration activity in the rest of the UK (either through existing onshore licences or as a consequence of the 14th onshore oil and gas round) will help to provide answers to the viability and consequential scale of the industry in Wales. Also there is the potential for CBM activity to occur at a faster rate in Wales, given the existing evidence and easier production route.
- **Regulatory and Permitting Regimes**. It is the view of DECC and the existing regulators that the application and enforcement of the existing regulatory framework ensures that effects of individual exploration activities are identified, assessed and mitigated to an acceptable level. However, whilst the system is seen by some as being unduly complex[2], the UK Government does not have any plans for any significant amendments to requirements or responsibilities. It won't be until the exploration industry has an opportunity to demonstrate that it can undertake unconventional oil and gas exploration activities in a manner that does not lead to unacceptable adverse effects that public acceptability of the technologies required will be achieved. Natural Resources Wales (NRW) and other regulators continue to review their regulatory approach as the industry develops so that high standards of environmental protection continue, protecting people as well as the environment.
- **Access to Specialist Equipment and Skills**. In order to respond to the possible growth in onshore exploration and production, the UK oil and gas service industry would need to grow. The current capacity of the UK service industry to undertake onshore shale operations is limited, with few drilling rigs and even fewer units that can hydraulically fracture. Although research has been undertaken and new initiatives launched (the National College) to help prepare for development, the reality is that indigenous supply chains and skilled workforces take time to develop as awareness, confidence and investment align.

[2] House of Lords Economic Affairs Committee (2014) 3rd Report of Session 2013–14, The Economic Impact on UK Energy Policy of Shale Gas and Oil

- **Access to Infrastructure**. When compared to other parts of the world, access to transport networks are unlikely to be the same barrier. However, consented access to water, waste water infrastructure and/or to gas distribution networks may be a constraining factor on development both in Wales and parts of the UK.

International Evidence on Economic Impacts

xi. By 2012 there were over 7,700 unconventional gas well completions[3] in the lower 48 US states, producing 36 billion cubic feet (bcf) of unconventional gas a day. By 2035 this is estimated by IHS, a US research institute, to rise to 80 bcf a day from 11,200 unconventional wells (although these estimates vary widely). Given the extent of this development activity, the US has been the focus of much of the existing research assessing the national, regional and local socio-economic impacts.

xii. IHS estimate that unconventional oil and gas industry accounted for an annual capital expenditure of $87bn in 2012, with much of this expenditure sourcing inputs from within the US due to the breadth and depth of the supply chains (in a large part due to the historic importance of the conventional oil and gas sector). This is estimated to have supported around 1.75 million jobs in the lower 48 US states. The available evidence points to large scale employment creation associated with the major US shale plays, such as Marcellus and the Eagle Shales.

xiii. The key determinants of the level and nature of employment creation include:

- The capital and employment intensive nature of the exploration and preparatory phase – although this is much shorter than the production phase, the vast majority of employment is supported at this phase (up to around 90%).
- Peripatetic nature of some employment – given the highly specialist nature of the drilling equipment, associated preparatory activities and the associated skills, a significant proportion of these workers tend to highly mobile, moving from one development to the next. Whilst this may limit local employment opportunities, it helps to support employment in the local service sector supporting the needs of these mobile workers (retail and hospitality).
- Long term nature of production phase employment - whilst production phase employment is much less than the earlier phases, it is of a longer duration (subject to the life of the well) and still well paid (and some studies suggest more highly skilled).
- Volume of drilling – given the greater levels of economic and employment impact associated with the exploratory phases of development, the overall rate are which new wells are consented and drilled is a key determinant of the overall employment impacts.

xiv. A range of studies have examined the potential economic and employment impacts in the UK should an unconventional oil and gas sector reach a large scale in the next two decades. This points to annual full time equivalent (FTE) employment supported of between 32,000 and 74,000 jobs at peak activity, with the range being influenced in part by varying assumptions about the rate and intensity of development and the level of expenditure retention within the UK, and on the nature of estimation techniques i.e. in particular on the extent to which modelled estimates take due account of the ability of the supply side of the economy to react to increases in demand from developers. We believe the higher estimates are, on balance, optimistic estimates of what could be achieved in reality.

xv. These studies also point to the economic benefits to the UK of a substantial and cheap additional supply of natural gas and a source of feedstocks for the chemical industry. Given the integrated

[3] HIS (2012) Well Completion is the process of preparing a well, after drilling, for production.

nature of the European energy market, the available evidence suggest that the potential for reduced energy prices will be dependent on the overall supply of these unconventional oils and gas at an European level as well as wider energy supply issues.

Potential Development Activity and Economic Impacts in Wales

xvi. Given the uncertainty over the recoverable shale and CBM reserves within Wales and the scale at which development activity may occur over the next two decades (the assessment period), scenarios have been used to examine the potential economic impacts which might arise within Wales (measured in terms of employment and gross value added in particular). These have also been used to explore whether higher levels of activity might be associated with the expansion of the supply chain, as indigenous companies invest to capture the opportunities and inwards investors are attracted into Wales.

xvii. The scenarios were informed by a range of sources including the review of other impacts studies, desk analysis of the possible unconventional gas resource in Wales and consultants with a wide range of organisations both in Wales and elsewhere in the UK. They combine both shale gas and CBM activity, but do not take account of gasification activity as too little is known about the potential for this to occur in the future in Wales and the potential expenditure and economic impact if it were to.

xviii. The summary table below provides an overview of the key assumptions and outcomes. The level of GVA and employment supported under the different scenarios reflect the assumptions about the scale of activity and scope to retain activity and expenditure within Wales (see sections 5 and 7 for a fuller explanation). The highest absolute and relative employment impacts are for the high scenario with between 270 and 630 average annual FTE jobs (direct, indirect and induced) depending on the intensity of drilling activity.

xix. The generation of wealth and employment will occur across a broad range of sectors in the Welsh economy (focused on extraction, manufacturing and service sectors), although this will be greater under the higher scenarios as the supply base adapts to some degree to the opportunities which arise. These are potentially important wealth and employment benefits underpinned by the growth of an unconventional gas sector and the associated supply chains and providing a range of new job opportunities (some of which will be relatively well paid).

xx. It is important to bear in mind that the assessment is shaped by a range of uncertainties and these are reflected in the brand ranges for the economic impact estimates. Production conditions in Wales would be very different from that in the US, and even if the primary production conditions were comparable, developers in Wales would face a very different mix of planning constraints to those that US firms have typically faced.

xxi. Whilst there are a range of uncertainties affecting the speed and scale of development across the UK as a whole, the pace of development in Wales is likely to be slower than in other parts of the UK and it is not likely to benefit from any first mover advantage in terms of the development of its supply chain. In this context the estimates should be viewed as illustrative and in the opinion of the authors the high activity scenario is on balance less likely to occur in the timescale for this assessment given the wider uncertainties attendant on development in the sector.

Summary of the Lifetime Economic Impacts in Wales for the Three Unconventional Gas Development Scenarios			
	Low Scenario – 'Business as Usual'	**Medium Scenario – 'Step up in Activity'**	**High Scenario – 'Step Change'**
Development Mix	Three CBM pads, with between 12-18 wells drilled and productive in total; no shale gas activity	Four CBM pads, with between 16-24 wells drilled and productive in total; One shale gas pad, with between 10 vertical wells and 24 wells with laterals.	Twelve CBM pads, with between 48-72 wells drilled and productive in total; Eight shale gas pads, with between 80 vertical wells and 192 wells with laterals.
Overall Lifetime Expenditure	£9.2 - £13.1m	£106.8 - £235.0m	£757.1 - £1,780.4m
% Retained Lifetime Expenditure in Wales	32%	32%	38%
£m Retained Lifetime Expenditure in Wales	£2.9 - £4.2m	£34.2 - £75.2m	£287.6 - £676.6m
Total GVA	£1.7 - £2.4m	£21.1-£46.6m	£170.4 - £400.4m
Total GVA per £1m spend	£0.6m	£0.6m	£0.6m
Annual Average GVA	£0.1 - £0.4m	£1.4 - £3.1m	£11.4 - £69.3m
Total Employment (FTE years)	Less than 100	500-1,100	4,000-9,400
Annual Average Employment (FTEs)	less than 10	30-70	270-630

Source: Cardiff University and Regeneris Consulting

Other Economic Impacts

xxii. There has been a lot of interest in the potential for new unconventional gas supplies in the UK and Europe to provide increased energy security and lower energy and feedstock supplies due to the experience in the US. However, in comparison, the US comprises a largely self-contained gas market and one where the exploitation of shale and other unconventionals represented a very significant shift in the supply of fuels and feedstocks.

xxiii. Neither of these is currently true for Wales or likely to occur in the timescale considered within this study. Wales is part of a UK electricity and gas grid, and operates in a gas market where prices are largely set at a European level and the cost of transportation (along the gas grids at least) is low. Added to this is uncertainty about the location of any processing which may be required for Welsh shale gas/methane prior to use, and the attitude of gas owners to contracting for product sales across wide geographies and to the highest bidder.

xxiv. The likelihood of Welsh origin gas being used in Wales is not high, and even where this is the case it will be under UK or EU market prices. This is not to exclude specific, mutually beneficial two party contracts (as was the case between Wylfa Nuclear Power Station and Anglesey Aluminium, and see also more recently plans for Ineos at Grangemouth in Scotland to invest in the shale gas resource). However, the geographically distributed pattern of extraction activity and more uncertain nature of shale and CBM exploitation (for example links to the scale of the exploitable resource, planning issues and other development uncertainties) may to some extent limit the potential for this regional partnering.

xxv. While Wales has relatively high levels of employment in energy intensive sectors it is unlikely that the extent and the timing of shale gas production would lead to any significant investment effects in the period covered by this study.

Skills

xxvi. The scope of the skills challenges related to the development of unconventional oil and gas are understood fairly well by industry and policy commentators. Higher level skills are more important in the exploration and post production phases, while the sector needs the support of a wide range of vocational and blue collar technical occupations throughout the operational life of any site.

xxvii. What is less well understood is the degree to which skills demand will be conditioned by the existing offshore operations and international service companies. Given current industry structures, it seems more likely that higher skilled workers will be procured internationally or through existing service providers which operate (and indeed recruit) at a national level. This leaves some scope for the provision of locally sourced technical and vocationally qualified workers, particularly in *locally* procured services. This certainly could have an impact in creating additional skilled and possibly well paid employment in areas with low levels of employment.

xxviii. The evolving skills infrastructure in unconventional oil and gas is heavily predicated on adapting existing offshore standards and roles. There is no reason why Welsh providers and institutions could play not an important role in this process, but currently there is little sign of any strategic engagement.

Impacts on Infrastructure

xxix. The assessment has also considered the potential implications of the growth of unconventional gas extraction for resources and infrastructure within Wales, including water supply and waste water treatment, transport infrastructure and ancillary infrastructure required to transport the extracted gas by pipeline to the main gas network (or its use in power generation as part of the energy mix and any increase in capacity to enable this).

xxx. This aspect of the assessment has been undertaken at a high level given the uncertainties over the precise locations of future development activity and how these relate to the types of infrastructure being considered. The analysis suggests that only the level of potential activity assumed under the high scenario (and the high intensity range within this scenario) could any infrastructure constraints at this spatial level of analysis be encountered, with the main constraints being around the supply of water and wastewater treatment (associated with flowback). However, this will depend on the location and scale of development compared to the available supply and associated capacity of the infrastructure, which will need to be tested through specific environmental impact assessment for proposed exploration and production activity. There could also be other infrastructure constraints at specific locations.

Local Community Impacts

xxxi. The study also considered the range of socio-economic benefits and disbenefits that the development of unconventional oil and gas may have on the local communities which host these activities. These may include the benefits associated with the access to employment and related training, increased demand for local goods and services and community benefits packages (through the voluntary scheme proposed by UKOOG), as well a range of potential disbenefits associated with the disruption to local communities due to protests, loss of amenity and environmental quality (associated with visual, noise and air quality impacts) and pressure on local social and community infrastructure (through the demands of and use by mobile workers).

xxxii. Although again subject to a great deal of uncertainty associated with the scale, location and timing of development activity, as well as the potential for these impacts not yet being tested thoroughly within the UK, the current evidence tentatively suggests:

- The potential to access employment opportunities on or close to site (with the developer or first tier suppliers) by local residents may be limited, although there will be a range of economic activity and hence jobs supported locally associated with the supply of a range of goods and services (e.g. in retail, hospitality, etc.). Nevertheless, these may still be important benefits for communities which are affected by high unemployment.
- The community benefit payments could represent significant additional income for local communities although the potential to secure long term benefits for these communities depends on the scale of the payments and the mechanisms put in place for allocating and spending this income.
- Many of the disbenefits associated with development that local communities experience are likely to be concentrated during the exploratory and preparation period and hence short term in their nature. We would expect these disbenefits, where they are significant in EIA terms, to be mitigated through the planning and regularity process.

Recommendations

- Given the paucity of evidence on the expected costs of production in Wales and associated geological conditions, the Welsh Government could support additional exploratory research into the scale and location of the unconventional gas reserves in Wales in collaboration with the private sector. The Welsh Government should also develop a watching brief on current and expected unconventional gas developments in the UK and Europe to better understand the likely local economic consequences of such development.
- It is recommended that Welsh Government, in considering policy responses to unconventional gas development, is careful in drawing any conclusions from social or economic impacts generated from studies in the US where production, regulatory and market conditions are very different.
- The Welsh Government and other stakeholders involved in skills planning and provision within Wales should seek to collaborate with the partners involved in the delivery of the proposed National College for unconventional gas in England. This would help to ensure that appropriate skills provision occurs within Wales and meets the needs of the industry locally as the sector grows.
- The economic and employment impacts estimates demonstrate the potential to secure economic benefits from extraction and production within Wales, arising across a range of sectors. The scope to achieve the higher levels within the ranges presented can be promoted through measures to raise awareness and to promote the supply chain opportunities, as well as business support provision to enable potential suppliers to be ready to take advantage of the opportunities. These actions should be coordinated between Welsh Government, sector bodies and the development industry. Special attention should be given to parts of the Welsh supply chain in professional services and manufacturing that work with the general oil and gas sector at home and overseas, and where there could be skills to meet the demands of an emerging unconventional gas sector.
- The economic impacts cited in this report make a series of assumptions about the ability of the local supply side to react to new opportunities that could be associated with an increase in the demands of an unconventional gas sector. It would also be useful to consider the expected impacts in the context of different assumptions about the ability of the supply side to meet these demands.
- There is scope to develop a centre of excellence for unconventional gas within Wales, with a particular focus on developing and sharing expertise in terms of the available resource and extraction technologies (and other parts of the supply chain).
- Proactive measures to promote best practice in the administration and use of community benefit payments should be put in place, as they have for general energy-related investments in Wales and Scotland. The reason for community benefits in the case of the unconventional gas development would need to be made more transparent for local communities. An emphasis might be upon providing a basis for securing long term socio-economic benefits for the communities which host the developments. Here it is recommended that best practice that has been adopted in selected on-shore wind projects in Wales be applied, and with a strong emphasis on the use of funds in building community capital. Careful consideration would need to be given to the level of community payments and the administration of funds at a local level.

1. Introduction

Background

1.1 The exploitation of unconventional gas in the UK, covering shale gas and oil, coal bed methane and underground coal gasification, is at an early stage. However, it has been the focus of much interest due to the potential to provide additional security of supply, to enhance the UK's energy mix and to potentially provide a lower cost energy source. Its potential to sustain jobs in the oil and gas industry and to generate tax revenue is also driving interest.

1.2 However, there remains considerable uncertainty about the amount of resource and the extent to which this is technically or economically recoverable. Various strategic studies have been commissioned by DECC for the UK as a whole and in areas of the UK considered to be most prospective for gas and oil. The Welsh Government commissioned a study on the potential unconventional gas resource in Wales.

1.3 It is recognised that the industry has potential to bring significant economic benefits to the UK and to particular locations. This has focussed on shale gas in particular, with widely differing estimates of the scale of employment supported. At the same time there are concerns about the potential environmental and social impacts of particular technologies and the impact they may have on host communities, and particular sectors (e.g. tourism, intensive gas using sectors). Given that the industry in Wales is in its infancy, there is an opportunity to consider the potential socio-economic impacts of unconventional gas for Wales.

1.4 This study will make an important contribution to policy development on unconventional gas in Wales. Whilst the Welsh Government does not have full devolved responsibility for energy policy, it does have various regulatory, policy, fiscal and resourcing mechanisms available to influence the development of the sector.

Definitions and Terminology

1.5 The study covers shale gas (although oil is also relevant but less common in Wales), coalbed methane (CBM) and gasification. Whilst shale gas and CBM refer to specific fossil fuels, gasification refers to one particular technique for extracting product gas including methane. Figure 1.1 illustrates the geological circumstances in which shale gas and CBM typically occur.

NOTE

The economic impacts outlined within this work are based on policies in place as of January 2015.

The following changes to policies have occurred between January and June 2015:

- Notification direction from the Minister for Natural Resources to local planning authorities on 13 February requires the referral of applications for unconventional gas and oil that involves unconventional extraction techniques (including hydraulic fracturing) to Welsh Ministers if the local planning authorities are minded to approve them.

- The Infrastructure Act (12 February 2015) contains provisions relating to environmental and planning safeguards for unconventional gas developments.

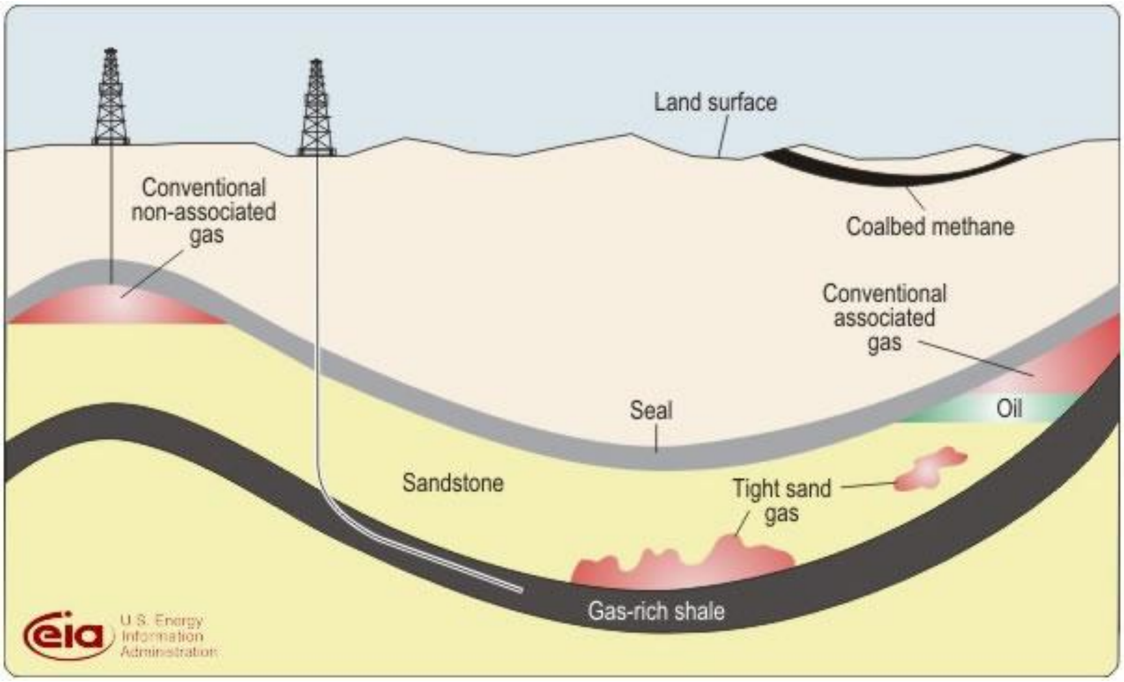
- On 1 April 2015 certain functions passed from the Department of Energy and Climate Change (DECC) to the Oil and Gas Authority (OGA). OGA is responsible for regulating offshore and onshore oil and gas operations in the UK including oil and gas licensing.

- Powers for a Purpose: Towards a lasting Devolution Settlement for Wales published on 27 February commits the UK Government to devolve to the National Assembly the licensing of onshore oil and gas underlying Wales.

- On 20 April the Minister for Economy Science and Transport issued a Written Statement on Energy, setting out the Welsh Government's vision for energy which is to:

    - safeguard and maximise the Welsh energy position through strong leadership across government;
    - maximise the benefit to Wales of the transition to low carbon generation, for businesses, households and communities;
    - maintain a business friendly, competitive environment for investment and affordable supply, and
    - seek to secure parity and increased influence within the UK , and wider afield, for Wales and Welsh interests.

Figure 1.1 Illustration of the Geological Setting for Shale Gas and CBM Resources



Source: US Energy Information Administration

1.7 More precise definitions of each are set below for information.

Coalbed Methane

Virtually all coals contain some methane as the result of coal formation which either adsorbs into coal micropores (<2nm) or is dispersed in pore spaces surrounding it, with the gas absorption being related to the pore and structure development of coal. As pressure is reduced, gas is released from the coal, diffuses through the coal matrix and flows through the fracture system of the coal.

Coalbed methane production can be subdivided into three categories: coal mine methane (CMM), abandoned mine methane (AMM) and coalbed methane (CBM) produced via boreholes from virgin coal seams. This includes the recovery of methane prior to mining taking place. Virgin Coal Bed Methane (VCBM) describes the recovery of methane from seams which have otherwise been untouched (i.e. they have not been previously mined) and which will remain unmined and is hence worked from surface boreholes. The quantity of gas released depends on gas content, and the permeability and thickness of the coal seam. There may be some trade-off whereby a coal seam of good thickness and permeability can compensate for low gas content, though seams of high permeability may have increased water disposal problems.

Virgin coalbed methane extraction generally requires seams thicker than 0.4m at depths between 200 and 1,500m (the limit of conventional mining). Any shallower and the coal is likely to have lost its gas by natural leakage, while at depths greater than 1,500m the yield is unlikely to cover drilling costs (though new technologies may eventually permit the use of deep coal resources).

Shale Gas

Shale gas refers to natural gas that is trapped within shale formations. It is part of a range of formations identified for unconventional gas exploration, ranging from tight gas sands, gas shales to coalbed methane. Shale is predominantly comprised of very fine-grained clay particles deposited in a thinly laminated texture, interspersed with organic matter. Following compaction, the pore water is expelled, resulting in a low-permeability layered rock, with each of the layers acting as a barrier to fluid migration.

The permeabilities (the ability of fluids to pass through them) of typical shale are very low compared to conventional oil and gas reservoirs (<0.1 mD in shales versus >1 mD in conventional reservoir sandstones) which means that hydrocarbons are effectively trapped and unable to flow or be extracted under normal circumstances. A combination of horizontal drilling and fracture stimulation technology is required to enable economic extraction of oil or gas from shale and other rocks with low permeability.

Underground Coal Gasification

Underground coal gasification is a process by which air, oxygen and steam are injected into coal seams at depth in order to partially combust the coal. The injectant reacts with the coal and produces heat, hydrogen, carbon monoxide and methane and in some seams, sulphur gases.

1.8 This report refers in various places to the unconventional resources and reserves, as well as the extent to which they are technically and economically recoverable. Definitions of these various measures used in the report are provided below.

Resource	Resource or total resource, or gas-in-place (GIP) refers to the volume of gas trapped in shale rock; the British Geological Survey uses this measure.
Technically recoverable resources (TRR)	The TRR are the estimated volumes of gas that could be produced with current technology, regardless of oil and natural gas prices and production costs. US agencies use this measure.
Economically recoverable resources (ERR)	ERR are resources that can be profitably produced under current market conditions. The economic recoverability of oil and gas resources depends on three factors: the costs of drilling and completing wells, the amount of oil or natural gas produced from an average well over its lifetime, and the prices received for oil and gas production.
Reserves	Reserves refer to a subset of discovered resources that are estimated to have a specified probability of being produced. Reserve estimates are commonly quoted to three levels of confidence, namely proved reserves (1P), proved and probable reserves (2P) and proved, probable and possible reserves (3P) although these terms are interpreted in different ways by different organisations. Shale gas resources are only classified as proved reserves in North America and these currently comprise only a small proportion of the estimated TRR.

1.9 The study examines the economic impact of the various phases of unconventional gas exploration and extraction. Whilst various categorisations of these phases are used by the industry and researchers, the definitions which are used in this assessment are summarised below. The durations of the phases are only illustrative as they will vary with local circumstances.

	Phase	Nature of Activity	Approximate Duration
Exploration	Phase 1: Non-Intrusive Exploration	Applying for permissions and scoping exercises - little or no on-site activity	1 year
	Phase 2: Exploration Drilling	Pad and transport preparation, Equipment transport, Drilling Well/Borehole,	3-4 years
	Phase 3: Initial Production Development	Fracturing, Water transport and flow back management, Well testing including flaring; Facility installation	
Production	Phase 4: Production O&M	Gas Production, Waste disposal, Chemical use, Monitoring	Site dependent
Wind Down	Phase 5: Decommission and Site Restoration	Plugging, Testing, Equipment removal, Monitoring; Survey and inspection, Restoration and Reclamation	1 year

Study Aims and Objectives

1.10 The general aims of the study are to:

- Understand, based on a current knowledge of the resource that might exist in Wales and in other parts of the UK, the potential economic and socio-economic benefits and disbenefits to Wales of unconventional oil and gas development onshore and immediately offshore, in both the exploration phase and commercial extraction stages.
- Identify the key economic and socio-economic variables that may be impacted by unconventional gas development, determine suitable indicators and establish a baseline against which the impacts can be assessed.
- Prepare a timeline on which impacts might be measured.
- Contribute to the policy development on unconventional oil and gas.

1.11 The specific objectives are to:

- Evaluate the current areas of capability in oil and gas development in Wales and in the UK.
- Identify the key businesses, supply chain, and academia with interests in unconventional gas development in Wales and by extension target potential areas for internal investment to develop the current expertise.
- Assess the economic and socio-economic impacts in the two key stages of development (planning/exploration/assessment stage and commercial extraction stage) for low, medium and high UK development scenarios, including and excluding commercial extraction in Wales.
- Evaluate the relevant skills required in the jobs likely to be directly and indirectly created, from the planning stage to well decommissioning, and their associated skills, qualifications and wage levels.

- To consider whether there is a requirement, and then the potential for developing education and training provision in Wales to meet this skill requirement.
- Estimate the potential socio-economic benefits and disbenefits to communities and local authorities hosting unconventional gas developments.
- Determine impacts of unconventional gas development on other economic sectors in Wales including (but not exclusive to) tourism, transport, energy intensive industry, refineries and other energy sources including renewables and other fossil fuels.
- Determine the impact of unconventional gas development on assets and resources in Wales including electricity transmission and gas networks, associated infrastructure and water supply.

Our Approach

1.12 The approach to the assessment, including all research tasks, were agreed with the Welsh Government. In summary the tasks covered:

Task 1 Review of Policy

- A review of the current energy policy at the UK and Wales level in relation to unconventional gas, current planning guidance, initiatives to promote exploration and extraction, economic development measures, community benefit initiatives, etc.

Task 2 Analysis of the Resource

- A review of the latest available evidence on:
  - The potential unconventional gas resource (globally, in the UK and in Wales), distinguishing between the types of gas resource
  - The key factors that determine the technically and economically recoverable resource, including their relevance to the conditions in Wales
  - The estimates of technically and economically recoverable reserves in Wales, if they are available.
- This task was also informed by consultations with the British Geological Society and the Coal Authority.

Task 3 Review of the Economic Impact Evidence

- A comprehensive review of the existing studies examining the national, regional and local impacts of unconventional gas exploration and extraction, including:
  - Economic, sectoral and labour market impacts
  - Energy market impacts (eg infrastructure and assets, pricing, security)
  - Local community impacts (including upon the tourism economy).
- The review focused in particular on the US literature due to the greater experience of developing unconventional gas at scale and hence the existence of a substantial evidence, but allowing for the geological, economic and fiscal differences between the US and UK.

Task 4 Review of the Unconventional Gas Supply Chain and Skill Needs

- The focus was on the supply chain and associated skill requirements associated with the different types of unconventional gas exploration and development, mapped by each development stage. We drew on the existing analysis undertaken for the UK (including studies by DECC and UKOOG), as well as consultations with the developers and operators, and a selection of primary suppliers.
- This was supplemented by detailed review of the current activity in Wales and a mapping of the supply chain and skills requirements against the capacity and capabilities of the Welsh business and skills base.

Task 5 Consultations

- As noted in a number of tasks above, an extensive programme of consultations was undertaken to inform various tasks. These consultations fell into the following groups:
  - Welsh Government staff (energy policy, economic development, planning policy, tourism and other agencies with a responsibility related to unconventional oil and gas (including Natural Resources Wales and Coal Authority)
  - UK Government departments (DECC, OUGO and BIS)
  - Industry representatives including UK Onshore Oil and Gas (UKOOG) and sector bodies with an interest in unconventional oil and gas
  - Current holders of Petroleum Exploration and Development Licenses (PEDLs) in Wales
  - A selection of existing significant contractors to the unconventional gas sector located within Wales or firms which would be well placed to enter the supply chain
  - A selection of major users of natural gas and related bi-products
  - A selection of local authorities in which licenses have or are likely to be issued
  - Providers or managers of major energy infrastructure in Wales which could be affected by changes in the energy mix.

Task 6 Development and Application of the Economic Modelling Framework

- Drawing on the review of experience elsewhere and consultations, the core approach to assessing economic impacts of the development of unconventional gas in Wales was discussed and agreed with Welsh Government. This used a number of development scenarios which combined shale gas and coalbed methane, together with assumptions about the phasing, cost and expenditure retention within Wales. The economic framework is based on an input-output approach. Section 5-7 set out more detail of the approach.
- The use of scenarios and ranges for assumptions enable the considerable uncertainty affecting future development of unconventional oil and gas to be managed in an appropriate way.
- Where appropriate, these scenarios also informed other aspects of the study which were less suited to quantitative assessment approach.

2. Policy and Planning Framework in the UK

2.1 This section provides a brief review of the policy context for unconventional gas in Wales, focussing on the relevant policies at the EU, UK and Wales level.

European Policy

Energy Policy

2.2 Shale gas and other unconventional sources are potentially important sources of energy supply in Europe, but due to early stages of exploration and other sources of uncertainty, it is yet unclear when this resource might become a significant source of supply. It is clear though that to support decarbonisation in power generation, flexible and secure gas supplies at competitive prices could play a role.

2.3 The European Commission has undertaken to assess Europe's potential for sustainable extraction and use of conventional and unconventional fossil fuel resources in order to further enhance Europe's security of supply. In line with this work, a number of studies on shale gas have recently been published. They are aimed at informing ongoing work to examine the need for a risk management framework in Europe and (if needed) the form it might take.

2.4 The studies commissioned by the European Commission include: a 2012 review of regional and global estimates of unconventional gas resources[4] by the UK Energy Research Centre (UKERC); a 2012 study which provided a comprehensive review of evidence of the risks to the environment and human health from hydraulic fracturing[5]; a study examining the macroeconomic impacts of shale gas extraction in the EU, released in March 2014[6]; and a study assessing the need for a risk management framework[7] (which included an extensive list of mitigation measures) published in August 2014. These studies aim to inform and shape the framework for unconventional gas policies within EU.

Regulation

2.5 The European Commission adopted Recommendation 2014/70/EU[8] in January 2014. The Recommendation sets out the minimum principles that may be used for Member States that are looking to develop the exploration and production of hydrocarbons using high volume hydraulic fracturing (HVHF)[9]. The principles aim to ensure that activities can be carried out with appropriate and adequate safeguards for the public and the environment, that resources are used efficiently and that the public is informed.

[4] UK Energy Research Centre (2012) A review of regional and global estimates of unconventional gas resources.

[5] AEA et al (2012) Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe, for DG Environment.

[6] European Commission (2014) Macroeconomic impacts of shale gas extraction in the EU.

[7] AMEC et al (2014) Technical Support for Assessing the Need for a Risk Management Framework for Unconventional Gas Extraction.

[8] European Commission (2014) Commission recommendation on minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high-volume hydraulic fracturing (HVHF).

[9] It is worth noting that high volume hydraulic fracturing (HVHF) is a relatively new term which has now been adopted in the Infrastructure Act 2015. HVHF means injecting 1 000 m3 or more of water per fracturing stage or 10 000 m3 or more of water during the entire fracturing process into a well. This does create the possibility that hydraulic fracturing could potentially occur below these water volumes, without triggering the Infrastructure Act fracking safeguards.

2.6 In addition, the Recommendation aims to provide a common framework for competent authorities, operators and the civil society to work within. In the Recommendation, the European Commission relies on the acquis communautaire[10] in the field of environmental protection, which is composed of numerous Regulations and Directives on the prevention of air pollution, water protection, protection of wildlife and flora, human health, treatment of wastes and protection of workers.

2.7 The Recommendation includes an invitation to Member States to report annually to the Commission (and the first time by December 2014) on the measures put in place in response to the Recommendation. Furthermore, the Commission is required to review the effectiveness of the Recommendation by August 2015. In particular, the review should include an assessment of the Recommendation's application, the progress of the information exchange on best available techniques, as well as any need for updating the Recommendation's provisions.

2.8 Natural Resources Wales worked closely with Welsh Government, DECC (Office of Unconventional Oil & Gas) and DEFRA in addressing/ responding to the Recommendation. By December 2014, Member States were asked to inform the Commission about the measures they have put in place in response to the recommendation. Defra consolidated a UK response, which incorporated response from each devolved administration. The key messages submitted by NRW were**:**

- Natural Resources Wales is satisfied that current regulations in Wales are adequate to protect the people and the environment during the exploration phase of the industry's development. We will keep this under review and will reassess our position should the industry develop to the appraisal and production stage.
- NRW noted that most of the minimum principles set out by the Commission mirror the work that they and other UK public bodies are already undertaking. However some aspects are beyond their existing powers to implement. Hence this raises the question what additional powers are required.
- NRW will continue to work with Welsh Government and UK Government to understand how they want us to take account of the Recommendation in our permitting approach. They will also reflect this in any future guidance that they are likely to produce.
- The Recommendation does not supersede existing European Directives. NRW will therefore continue to apply their current regulation until further notice.

United Kingdom

Energy Policy

2.9 The UK is legally bound to reduce its greenhouse gas emissions to at least 80% below 1990 levels by 2050 according to the Climate Change Act of 2008. In order to assess progress, the Energy Emissions Projections[11] are published by DECC, including projections of future energy demand. The most recent document published in 2014 shows that demand for natural gas by final user sector is projected to decrease from 54mtoe[12] in 2010 to 42mtoe in 2035. During the same time,

[10] The "acquis communautaire" covers all treaties, EU legislation, international agreements, standards, court verdicts, fundamental rights provisions and horizontal principles relating to environmental protection and so to shale gas. This is a common situation across most of the regulated industrial sectors.

[11] DECC (2014) Updates energy and emissions projections 2014.

[12] Million tonnes of oil equivalent.

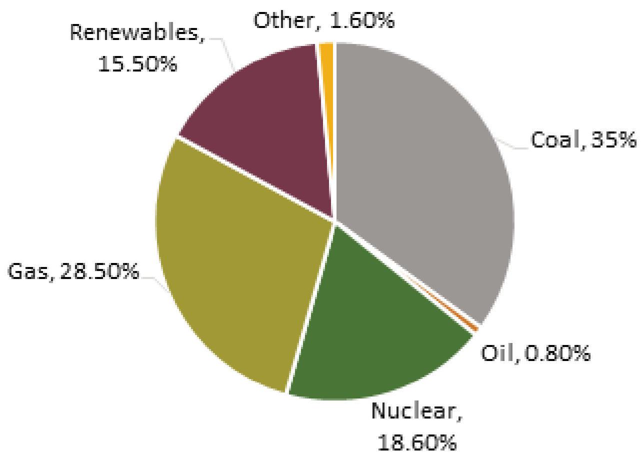
the share of renewables is projected to rise from 3 mtoe to 6mtoe, and electricity is also projected to rise from 28mtoe to 32 mtoe.

2.10 The UK government's latest comprehensive statement on the role of gas within the overall energy generation mix is contained in its Gas Generation Strategy. Gas is an integral part of UK's energy mix, where it plays a key role in electricity generation as well as being a transition fuel on the way to decarbonising the economy. Using natural gas in a modern gas-fired plant would reduce greenhouse gas emissions per kWh by half when shifting from the current world-average coal-fired power plant, evaluated using 100-year global warming potentials and so is viewed as a bridging fuel[13] towards a low carbon economy. In 2011, 40% of electricity was generated through gas, and gas power stations accounted for around a third of UK electricity generating capacity[14].

2.11 Beyond power generation, the same document states that gas was the most significant fuel overall in 2010, accounting for 38.5% of primary energy use, with the majority being used for heating, commercial and industrial sectors. This is forecast to fall in absolute and percentage terms to 2035, dropping to an estimated 34.4% share.

2.12 The UK energy policy is strongly focused on low carbon energy, moving increasingly towards renewables in order to meet the legally binding 15% renewable target by 2020 set out in the 2009 EU Renewable Energy Directive. The UK Renewable Energy Roadmap[15] has been updated in 2013 to take account of the latest data, and shows that as of second quarter of 2013, the share of renewables is at 15.5%, which is 5.8% more than the previous year (Figure 2.1**Error! Reference source not found.**). There is a particular focus on reducing the share of coal in the energy mix, along with other fossil fuels in the longer term.

Figure 2.1 Electricity Generation From Different Fuels, Q2 2013



Source: UK Renewable Energy Roadmap, 2013

2.13 In 2012 the UK Government published a statement on energy security[16] which includes six policy areas to ensure delivery of diverse energy supply and a robust infrastructure for consumers. These include resilience measures to reduce the impact of a sudden energy supply shock, policies

[13] Houses of Parliament (2011) POST Note: Unconventional Gas.

[14] Department of Energy and Climate Change (2012) Gas Generation Strategy.

[15] DECC (2013) UK Renewable Energy Roadmap.

[16] Secretary of State for Energy and Climate Change (2012) Energy Security Strategy.

on energy efficiency measures (Energy Efficiency Strategy), policy to maximise economic production of UK oil and gas resources through licensing rounds, a favourable fiscal regime for investment in the North Sea and through considering the potential for UK unconventional gas production. As the UK net gas import dependency is expected to rise to 70% by 2025 (around 50% currently), the Government aims to work internationally to ensure reliable supply, while delivering a reliable infrastructure network.

2.14 Given the current importance of gas in the UK, it is unsurprising that the general UK Government policy towards development of UK shale gas is supportive, as long as it can be shown that domestic gas production can be economic, safe and environmentally responsible. The 2014 Autumn Statement[17] states that the UK Government supports the development of unconventional oil and gas in order to provide energy security, as well as economic development and job creation.

2.15 The UK Gas Generation Strategy outlines the role of the Office for Unconventional Gas and Oil (OUGO), set up by the Department for Energy and Climate Change (DECC) in 2013. It is charged with promoting the safe, responsible, and environmentally sound recovery of the UK's unconventional reserves of oil and gas, and other forms of unconventional production such as coal bed methane. It works with HM Treasury to support the growth of unconventional energy industries by ensuring coherence between the regulatory, licensing and taxation regimes, as well as providing a framework to deliver benefit to local communities that accommodate development. OUGO is also intended to act as a single point of contact for investors, building confidence through ensuring a simplified and streamlined regulatory process.

2.16 The same document also notes that DECC is expanding onshore oil and gas licensing through the 14th Licensing round[18]. Bidding closed at the end of October 2014. Announcements of 14th round Licence (PEDL) awards had not been made at the time of this report being completed.

Regulation and Planning

2.17 In the previous (13th) round of onshore licensing, 60 applications for PEDLs were made for 182 blocks by 54 companies, 20 of which were for CBM. Subsequently, on 28 May 2008, the Secretary of State offered 93 PEDLs. Between 2000 and 2012, 341 onshore oil and gas wells have been drilled in the UK (including exploration, appraisal and development wells). An average of 26 wells were drilled in each year during this period, peaking in 2008 when 40 wells were drilled. In Wales, 6 PEDLs were issued, mainly for coalbed methane and mine gas.

2.18 This drilling activity is controlled by the regulatory and planning systems. Currently, the process of obtaining the consent to exploit shale gas and coal bed methane is the same as for conventional gas. The Oil and Gas Authority (DECC pre 01 April 2015) issue a licence that grants exclusivity to operators in the licence area to explore for and produce petroleum. Operators wishing to drill a well must negotiate access with landowners, and if the well encroaches on coal seams, permission must also be granted by the Coal Authority.

2.19 The operator then needs to seek planning permission from the local minerals planning authority (MPA), and consult with the environmental regulator (Natural Resource Wales (NRW) in Wales), who are statutory consultees to the MPA. The MPA will then determine if an environmental impact assessment (EIA) is required. Environmental permits, consents and licences from the

[17] HM Treasury (2013) Autumn Statement 2014.

[18] Following the Strategic Economic Assessment (SEA) in 2010, the assessment had been expanded in 2014 to take account of newly arising environmental implications, before making a decision on a new 14th licensing round

appropriate environmental agency will also be necessary, as well as permits from the Health and Safety Executive (HSE) and a consent to drill and frack from the DECC.

2.20 The UK has a goal-setting approach to regulation that requires operators to ensure and demonstrate to regulators that the risks of an incident relating to oil and gas operations are reduced to 'as low as reasonably practicable',[19] which should encourage continuous effort for improvement.

2.21 DECC has published Regulation and Best Practice guides for UK countries with the intention of providing greater clarity over the permitting and permissions process for unconventional oil and gas.

Support for the Development of Unconventional Gas

2.22 The UK Onshore Operators Group, which is the representative body for the onshore oil and gas industry in the UK, has published a Community Engagement Charter[20] where it outlined the following commitments:

- To provide benefits to local communities at the exploration/appraisal stage of £100,000 per well site where hydraulic fracturing takes place;
- To provide a share of proceeds at production stage of 1% of revenues, allocated approximately 2/3rd to the local community and 1/3rd at the county level;
- To consult openly and honestly with local communities at all stages, including in advance of planning and permission applications;
- Finally, the operators will publish evidence each year detailing how the commitments within the community benefits package are being met.

2.23 The UK Government has also shown support for the industry by making a series of proposals aimed to encourage safe and sustainable development, and a boost investment. In the 2013 Autumn Statement it was announced that companies will receive a tax allowance of 75% of capital spent on projects, and the tax rate on the remaining proportion of a company's profits would be reduced from 62 to 30%. The allowance was introduced with immediate effect from 5 December 2013 (Finance Bill 2014)[21]. The 2014 Autumn Statement introduced further measures to support the industry, including a new £5m fund to provide independent evidence to the public about the robustness of current regulatory regime, as well as reduction in the rate of the Supplementary Charge from 32% to 30%.

2.24 Furthermore, in January 2014 the UK Government announced that English local authorities would be able to keep 100% of business rates collected from shale gas sites.

2.25 In May 2014 the UK Government conducted a public consultation seeking views on a proposal to simplify underground access and exploitation of oil, gas and geothermal resources. Over 40,000 respondents replied to the consultation, with over 99% opposing the proposition to provide underground drilling access. Following the consultation, the UK Government released its response[22] which includes several intentions:

[19] Department of Energy & Climate Change (2013) Onshore oil and gas exploration in the UK: regulation and best practices.

[20] UKOOG (2013) Community Engagement Charter: Oil and Gas from Unconventional Reservoirs.

[21] HM Treasury (2013) Autumn Statement 2013.

[22] DECC (2014) Government Response to Consultation on Proposal for Underground Access for the Extraction of Gas, Oil or Geothermal Energy.

- Granting underground access rights to companies extracting petroleum resources and geothermal energy in land at least 300 metres below the surface
- A one-off voluntary community payment of £20,000 for each unique lateral well that extends by more than 200 metres laterally (alongside this will be powers to make such payments compulsory if companies fail to volunteer)
- A public notification system under which the company would set out drilling proposals along with details of voluntary payment.

2.26 Changes to access rights in England and Wales have been introduced through the Infrastructure Bill. Methane in coal rights rests with the Crown which authorises the Secretary of State to issue licences to search bore for and extract it. Ownership of coal resides with the Coal Authority who grant licences for coal exploration and extraction.

2.27 Methane Drainage licences (MDL) are also issued by DECC and provide permission to get coal mine methane (CMM) "in the course of operations for making and keeping safe mines whether or not disused". An MDL grants no exclusive rights and can overlap geographically with PEDLs. Each MDL typically covers one mine and there are currently 20 MDLs in the UK. Currently CBM is exempt from the UK Climate Change Levy (CCL), a tax on fossil fuels that have not otherwise been taxed.

Policy in Wales

Energy Policy

2.28 At the time of writing this report, energy policy is largely a reserved matter. However, as with the UK Government, it is the stated position of Welsh Government that it will endeavour to move towards a low carbon energy system that maximises jobs and long term benefits. Natural gas is seen as playing a key role in this transition process[23]. There are several objectives that have been set out for the energy system in Wales, forming part of the Welsh Government's Climate Change Strategy:

- Meeting the European Council's target for reduced emissions of 80-95% by 2050 compared to 1990 levels
- Meeting the environmental standards such as those for pollutants and waste
- Providing energy security and resilience
- Delivering an affordable and credible framework for long term investment through energy markets.

2.29 A key role in achieving these will be played by business, and the Welsh Government has committed to creating a stable environment for the necessary long term investment for the low carbon transition. This will involve the following goals:

- Firstly, to maximise the long term economic benefit for Wales through job creation in the energy sector
- Secondly, to ensure communities benefit from energy infrastructure developments and production

[23] Welsh Government (2012) Energy Wales: A Low Carbon Transition.

- Finally, to plan and manage the relationship between energy and natural environment in line with the ambition set out in "Sustaining a Living Wales".

2.30 The Welsh Government is seeking to maximise the benefit that energy developments can deliver for Wales. Their approach involves:

- Ensuring robustness of the energy infrastructure in Wales;
- Clear and consistent priorities within policies;
- Ensuring Wales and its communities benefits economically from energy developments;
- Delivering renewable energy;
- Ensuring energy efficiency;
- Unlocking the marine energy potential;
- Piloting and rolling out of next-generation smart living solutions.

2.31 The Welsh Government recognises the role of gas in the transition to a low carbon economy, and advocates a precautionary approach to the exploration of unconventional resources while currently exploring the potential economic, environmental and social impacts of the development in more detail.

Regulation and Planning

2.32 The regulatory and permitting process that would apply to unconventional gas in Wales is broadly the same as for the rest of the UK (and DECC have produced a version of the regulation roadmap specifically for Wales (in conjunction with Natural Resources Wales and the Welsh Government)). NRW has responsibility for most aspects of environmental permitting, rather than the Environment Agency which is responsible for these matters in England. Also MPAs are initially responsible for determining if an environmental impact assessment is required, with an appellate role for Welsh Ministers. The UK Government has the reserved power to issue PEDLs under the Petroleum act 1998. The UK Government has indicated that this power will be devolved to Wales in the future, as described in Powers for a Purpose[24].

2.33 Mineral Planning Policy Wales (MPPW) aims to ensure a sustainable pattern of mineral extraction within Wales. It clearly sets out that if the proposed extraction would demonstrably harm the environment, a planning permission should not be granted. The MPPW for onshore oil and gas requires development plans to indicate those areas where oil and gas operations are likely to be acceptable in principle subject to development control criteria being met in a particular case, as well as those areas where operations are unlikely to be acceptable. Policies should clearly distinguish between the stages of extraction according to the Petroleum Act 1998. There is a requirement for mineral planning authorities to establish the areas that are being licensed, and identify environmental and other constraints on production and processing in those areas.

2.34 The Welsh Government issued a clarification letter on the national planning policies that apply for onshore unconventional gas and oil development in July 2014, indicating that the general policy considerations set out in Minerals Planning Policy Wales are applicable in considering planning applications in Wales. The letter also refers to the responsibilities covered by other regulators outside of the town and country planning system.

[24] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/408587/47683_CM9020_ENGLISH.pdf

2.35 Notification Direction from the Minister for Natural Resources to local planning authorities on 13 February requires the referral of applications for unconventional gas and oil that involved unconventional extraction techniques (including hydraulic fracturing) to Welsh Ministers if local planning authorities are minded to approve them.

Summary

2.36 At the UK level the prevalent policy drivers tie in with reducing greenhouse gas emissions and increasing the share of renewable energy sources in the energy mix, while maintaining energy security. This makes gas an integral part of UK energy mix, as it plays a key role in electricity generation and acts as a transition fuel to decarbonising the economy.

2.37 While the demand for gas is projected to fall somewhat by 2035, UK import dependency is set to rise to c.70%, requiring extra measures to ensure energy security. As a result, the UK Government committed to maximising economic production of UK oil and gas resources, including the potential for UK unconventional gas production. The support for the industry includes the Office for Unconventional Gas and Oil (OUGO) set up in 2013, tax incentives and allowances and the steps that were taken to simplify underground drilling access for operators. The Community Engagement Charter introduced by UKOOG ensures that local communities benefit by receiving community payments and 1% of total revenues throughout the development process.

2.38 The Welsh Government is committed to moving towards a low carbon economy and sets out its ambitions for tackling climate change in the Climate Change Strategy for Wales. While meeting these climate change goals, the Welsh Government aims to maximise the benefit to the people of Wales and create wealth and employment in the process. Its approach to unconventional gas is currently precautionary while it considers the evidence and undertakes further research into benefits and disbenefits of unconventional gas production in Wales.

3. Unconventional Gas Resource in Wales

3.1 This section sets out:

- An overview of existing research on available shale and CBM resource, providing global resource context for resource and reserve estimates in UK
- A review of evidence on Welsh resources and reserves, including views and opinions from consultation with the Coal Authority and the British Geological Survey (BGS)
- The factors which are likely to influence the extent of extraction within Wales over next twenty years.

Global Resources

3.2 In 2013, based on an assessment of 137 shale formations in 41 countries outside the United States, the US EIA estimated[25] the technically recoverable reserves (TRR) of shale oil and gas resources for the world as follows:

- 350 billion barrels (bbls) of world shale oil resources
- 7,300 trillion cubic feet (tcf) of world shale gas resources.

3.3 By comparison, the globally technically recoverable resource of conventional gas has been estimated at 15,256 tcf (432 trillion cubic metres)[26] so current estimates of shale gas represent some 32% of all technically recoverable gas.

3.4 Nearly 80% of the world's estimated technically recoverable shale gas resources are found in just 10 countries (see Table 3.1). The UK Energy Research Centre (UKERC) conducted a comprehensive review of 62 studies that provide original estimates of regional and global shale gas resources[27]. This suggested that the United States holds around 10% of the global TRR of shale gas, while Europe holds around 8%. Shale gas resources could however be much more important at the regional level. For example, shale gas may represent 34% of the remaining TRR of natural gas in China, 36% in Canada, 48% in Europe and 31% in the United States. For Europe currently, 89% of annual gas demand is imported and one estimate suggest shale gas could reduce European import dependency by up to 27% by 2035[28]. If such estimates are borne out, shale gas could represent a significant alternative to importing gas from other regions and provide a degree of energy independence and security.

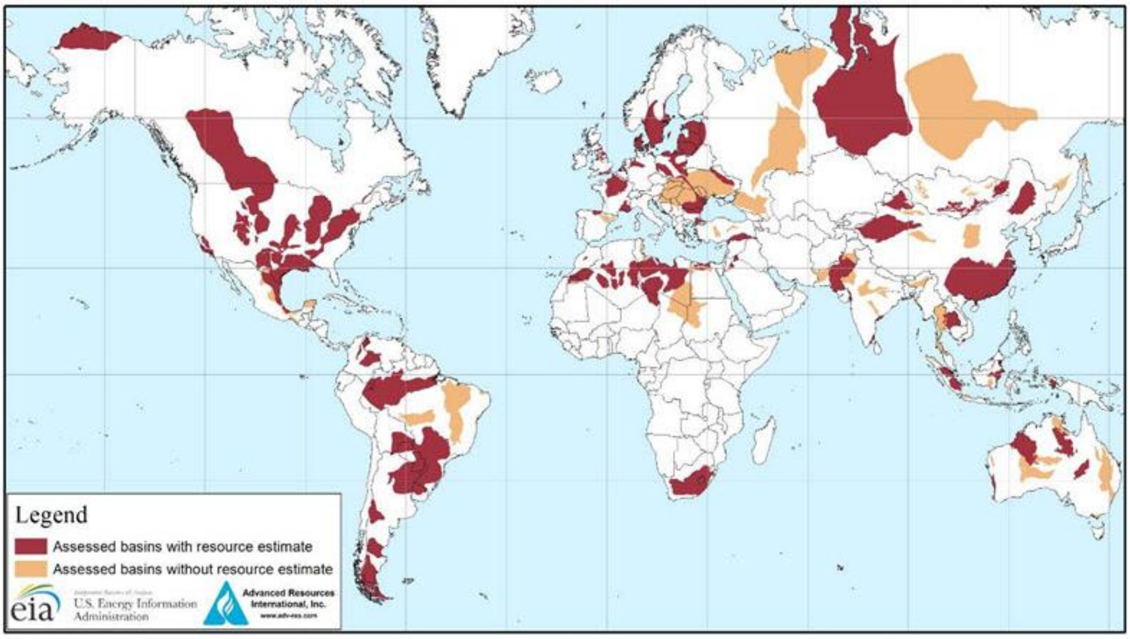
[25] US Energy Information Administration (2013) Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States.

[26] House of Commons Energy and Climate Change Committee (2013) The Impact of Shale Gas on Energy Markets Seventh Report of Session 2012–13, para22

[27] McGlade, C, J Speirs, and S Sorrell (2012) A review of regional and global estimates of unconventional gas resources: A report to the Energy Security Unit of the Joint Research Centre of the European Union.

[28] Poyry (2013) Macroeconomic Effects of European Shale Gas Production

Figure 3.1 Basins with Assessed Shale Oil and Gas Formations, May 2013



Source: United States basins from U.S. Energy Information Administration and United States Geological Survey; other basins from ARI based on data from various published studies

Table 3.1 Top 10 Countries with Technically Recoverable Shale Gas Resources (TRR)

Rank	Country	Shale gas (trillion cubic feet)	Shale gas (trillion cubic metres)
1	China	1,115	31.6
2	Argentina	802	22.7
3	Algeria	707	20.0
4	U.S	665	18.8
5	Canada	573	16.2
6	Mexico	545	15.4
7	Australia	437	12.4
8	South Africa	390	11.0
9	Russia	285	8.1
10	Brazil	245	6.9
	World Total	**7,299**	**206.6**

Note: based on U.S. shale production experience, the recovery factors used ranged from 20 percent to 30 percent, with values as low as 15 percent and as high as 35 percent being applied in exceptional cases

3.5 Shale gas exploitation is particularly advanced in the US due to advances in horizontal drilling and hydraulic fracturing which has led to a rapid growth in the production of shale gas after 2008. The International Energy Agency (IEA) announced in 2009 that unconventional gas had "*changed the game*" in North America. In 2012, shale gas constituted 35% of total US gas production and it is forecast that it will account for 50% of total US gas production by 2040[29].

3.6 Recent experience with shale gas in the United States and other countries suggests that economic recoverability can be significantly influenced by above-ground factors as well as by geology. Key above-the-ground advantages in the United States and Canada that may not apply in other UK and some European locations include:

- Private ownership of subsurface rights that provide a strong incentive for development
- Availability of many independent operators and supply chains with key expertise and suitable drilling rigs
- Pre-existing pipeline infrastructure
- Availability of water resources for use in hydraulic fracturing.

3.7 In consequence, the extent to which the current technical recoverable global estimates will be realised and the pace with which they will be extracted remains uncertain. However, the North American experience suggests that shale gas will be a significant factor in meeting future global energy needs.

Unconventional Gas Resources in the UK

3.8 The UK has abundant shales at depth, although their distribution is not fully understood currently. The British Geological Survey (BGS) is investigating the location, depth and properties of the shale as well as the processes that lead to economic accumulations of gas. Specifically, the Department of Energy and Climate Change (DECC) has commissioned studies by the BGS of shale deposits in prospective areas (those thought most likely to contain shale gas and oil resources). Studies by the BGS have to date been completed of the Bowland-Hodder unit in Northern England[30] (2013), the Midland Valley of Scotland[31] (2014) and the Weald Basin in South East England[32] (2014). Figure 3.2 sets out the broad locations and extent of these resources within the mainland UK.

3.9 The resource estimates are in the form of a range to reflect geological uncertainty:

- Bowland-Hodder unit resource estimates of gas (not proven to be recoverable) as between 23.3 and 64.6 trillion cubic metres (tcm).
- Midland Valley of Scotland resource estimates of gas to be between 1.4 and 3.8 tcm, with the central estimate for the resource being 2.3 tcm. The range of shale oil in place is estimated to be between 3.2 and 11.2 billion barrels (bbl), with the central estimate for the resource being 6.0 bbl.

[29] US Energy Information Administration (2013) Annual Energy Outlook 2013.

[30] BGS (2013) The Carboniferous Bowland Shale gas study: geology and resource estimation, for DECC.

[31] BGS (2014) The Carboniferous shales of the Midland Valley of Scotland: geology and resource estimation, for DECC.

[32] BGS (2014) The Jurassic shales of the Weald Basin: geology and shale oil and shale gas resource estimation, for DECC.

- Weald Basin of South East England has no significant gas resource using the current BGS geological model. This is mainly because the shale is not thought to have reached the geological maturity required to generate gas. The range of shale oil in place is estimated to be between 2.2 and 8.6 bbl and a central estimate for the resource of 4.4 billion bbl.

3.10 BGS has suggested that offshore shale formations are larger than those onshore, with a tentative resource estimate of 28.32 tcm (1,000 tcf) for the east Irish Sea Basin (based on Cuadrilla's figures on their adjacent onshore acreage). However, there is as yet no wider estimate of the UK offshore resource.

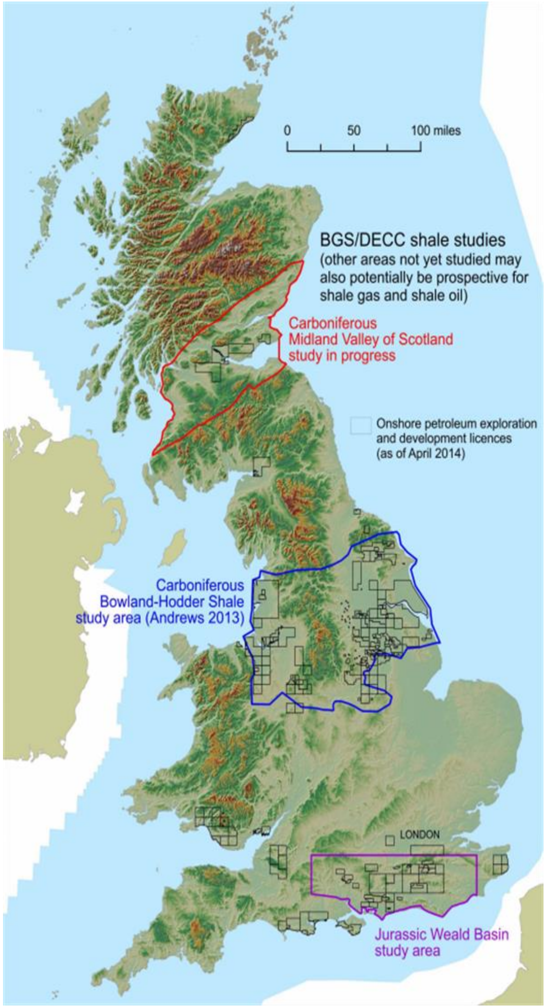
3.11 As more detailed geological information has become available following further exploration activity, shale gas estimates have been revised upwards over the last few years[33]. AMEC, part of the study team for this assessment, expect that the current estimates will be subject to further refinement following the availability of additional geological information arising from current and future exploration activity.

3.12 In total, these resource estimates provide a current range for onshore unconventional shale oil and gas in UK of:

- Shale gas: between 24.7 and 68.4 tcm
- Shale oil: between 5.4 and 19.8 bbl.

3.13 **It should be noted however that these estimates are of the resource and not of the reserve**. Recovery factors for unconventional gas for the US have ranged from 10% to 40% reflecting different geological areas, while recovery factors for conventional gas can be as high as 70–80%. However, the BGS has not provided an estimate of how much of the UK shale gas resource is technically and economically recoverable.

Figure 3.2 UK's Principal Shale Bearing Areas



The squares and blocks in this figure reflect the current onshore areas licensed by DECC for oil and gas exploration and production

3.14 In addition, non-geological factors such as market price, operating costs and the scale of development agreed by the local planning system will affect the amount of shale gas or oil produced[34].

3.15 Speculation on what resource estimates could mean for the UK is inevitable. For example, in the 2013 ENDS report, 'UK Shale Gas and the Environment', it was suggested that "*even if it*

[33] A BGS report prepared for DECC in 2010 indicated that the UK shale gas reserve could potentially be 150 bcm (5.3 tcf) but stressed that research into shale gas in the UK is in early stages, and ahead of drilling, hydraulic fracturing and flow testing, the estimate may prove to be invalid (Department of Energy and Climate Change, 2010).

[34] House of Commons Energy and Climate Change Committee (2013) The Impact of Shale Gas on Energy Markets Seventh Report of Session 2012–13, Volume I.

[economic recovery rates] were a pessimistic 5%, that would be equivalent to almost 19 years of UK consumption at current demand levels"[35] [when compared to UK's annual consumption of gas (100 bcm[36] in 2010 or 80 bcm in 2013) or more than 35 years of production when compared to the 37 billion cubic metres of gas produced in the UK in 2012].

3.16 It should be remembered that estimates of technically recoverable reserves have no implication for whether these reserves are economically viable at current prices, or in relation to other economically marginal sources of fuel that may become attractive following a price increase.

3.17 Irrespective of the recovery rate, whilst UK estimates of shale gas are important at the national level, they are modest when compared to global estimates of the technically recoverable resources.

Unconventional Gas Resources in Wales

3.18 Figure 3.3 shows the current 13th round petroleum exploration and development licences in Wales which are held by prospective developers, as well as the 14th round licences which are being offered by DECC.

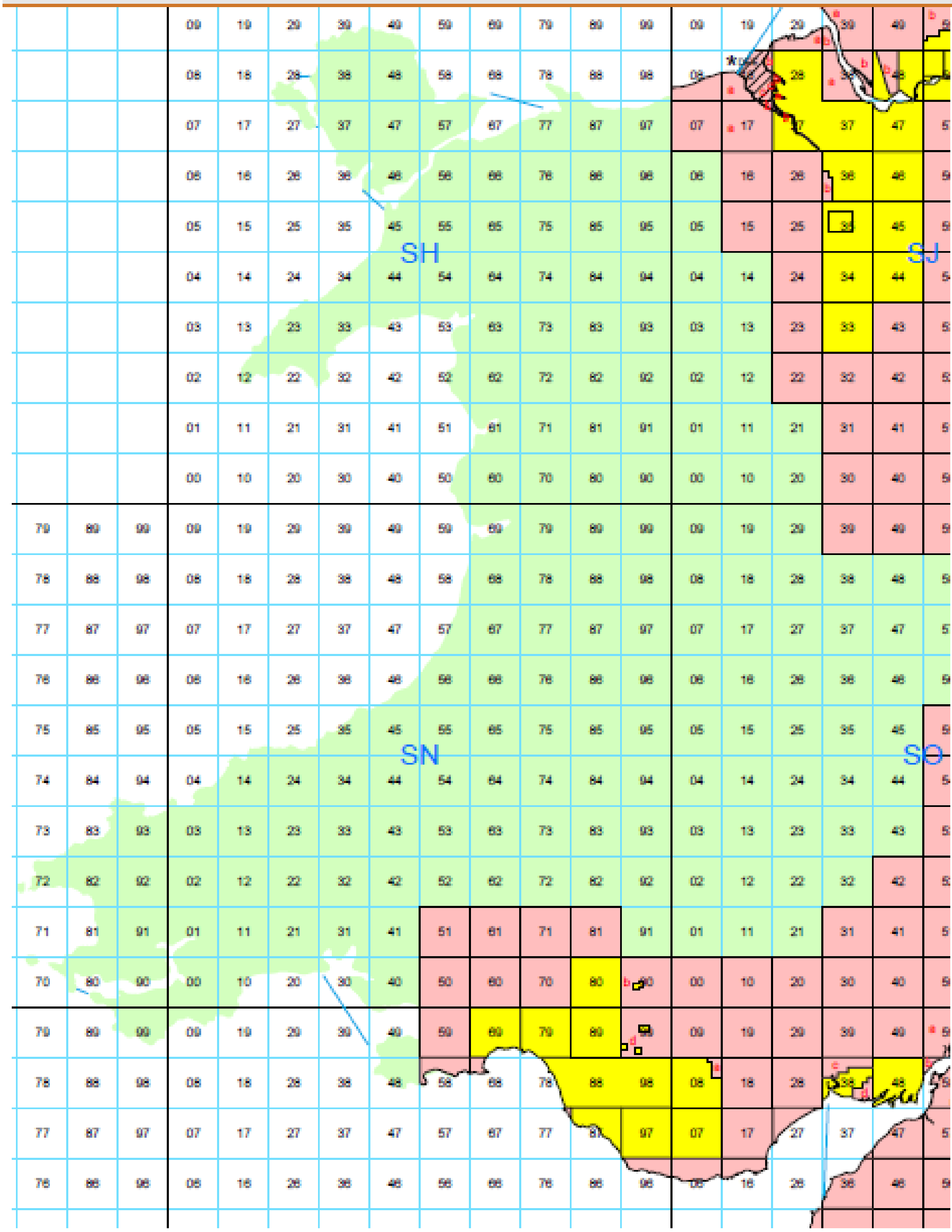
3.19 Potential unconventional gas resources in Wales are most likely to be found in association with coal seams or shales. Coal mining in Wales has generated an extensive archive of information describing the structure and composition of the coalfields. Unconventional gas from coal includes Coal Bed Methane (CBM), Abandoned Mine Methane (AMM), Coal Mine Methane (CMM), and Underground Coal Gasification (UCG). There are two main regions in Wales which are underlain by coal-bearing geological strata, much of which has the potential to produce methane. These are the South Wales Coalfield and the North Wales coalfields. The South Wales Coalfield covers an area of approximately 2,000 km^2 extending from Torfaen in the east to Carmarthenshire in the west. The North Wales coalfields covers an area of approximately 400 km^2 and crop out in a belt extending from Point of Ayr to Oswestry. The North Wales coalfields comprises of the Flintshire, Denbighshire and Oswestry coalfields. The Welsh coalfields extend offshore into the subsea (subsurface) from Swansea, Carmarthen and St Davids and into Liverpool Bay.

3.20 CBM and virgin coal bed methane (VCBM) refers to the gas naturally occurring within un-mined coal seams. Methane is recovered from un-mined coal seams via vertical or directionally drilled wells, drilled from the surface to meet the target coal seams. Most coal seams contain water and the process of dewatering can result in the production of significant quantities of produced water which may have elevated concentrations of salinity and metals that may require treatment prior to discharge. In Scotland at the Dart Energy site at the Airth field, for example, the produced formation water was treated to remove iron and then transported via road tankers for discharge in the nearby Firth of Forth.

[35] DECC (2012) Gross Gas Production Figures 2012, https://www.gov.uk/oil-and-gas-uk-field-data

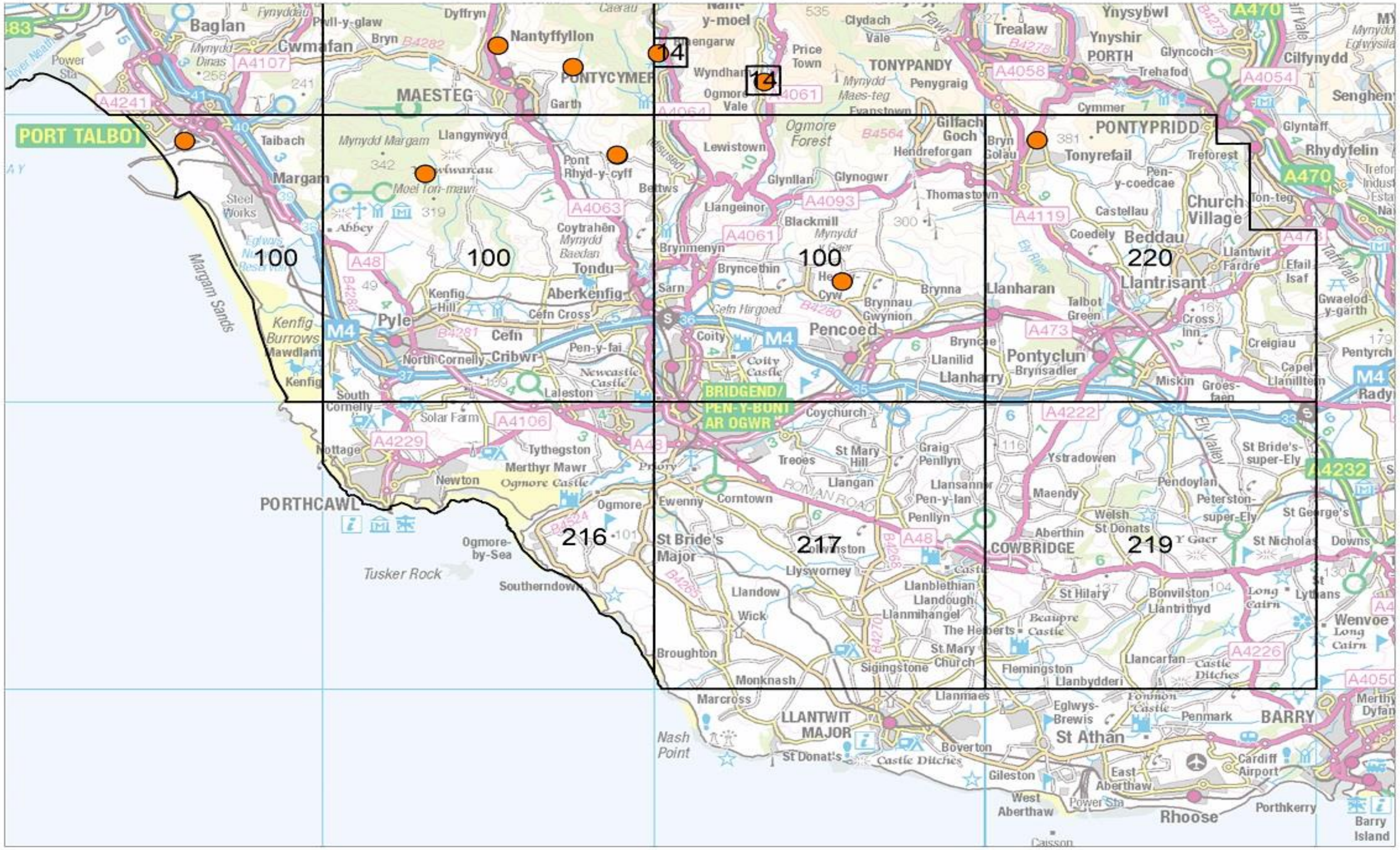
[36] House of Commons Energy and Climate Change Committee (2013) The Impact of Shale Gas on Energy Markets: Seventh Report of Session 2012–13, Volume I, 2013.

Figure 3.3 13th and 14th (under offer) Round Onshore Oil and Gas Licenses in Wales



Source: Source: DECC, 13th Round Licenses and 14th Onshore Round Licensing Blocks Under Offer, 2014; Note: 13th Round PEDLs are shown in YELLOW, whilst 14th round PEDLS available to licence applicants are shown in PINK

Figure 3.4 13th Round PEDL Licences in South and North Wales



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Pontardawe
Clydach
Hirwaun
ABERDARE
TREHERBERT
TREORCHY
Llwynypia
TONYPANDY
GORSEINON
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Baglan
Cwmafan
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The Mumbles
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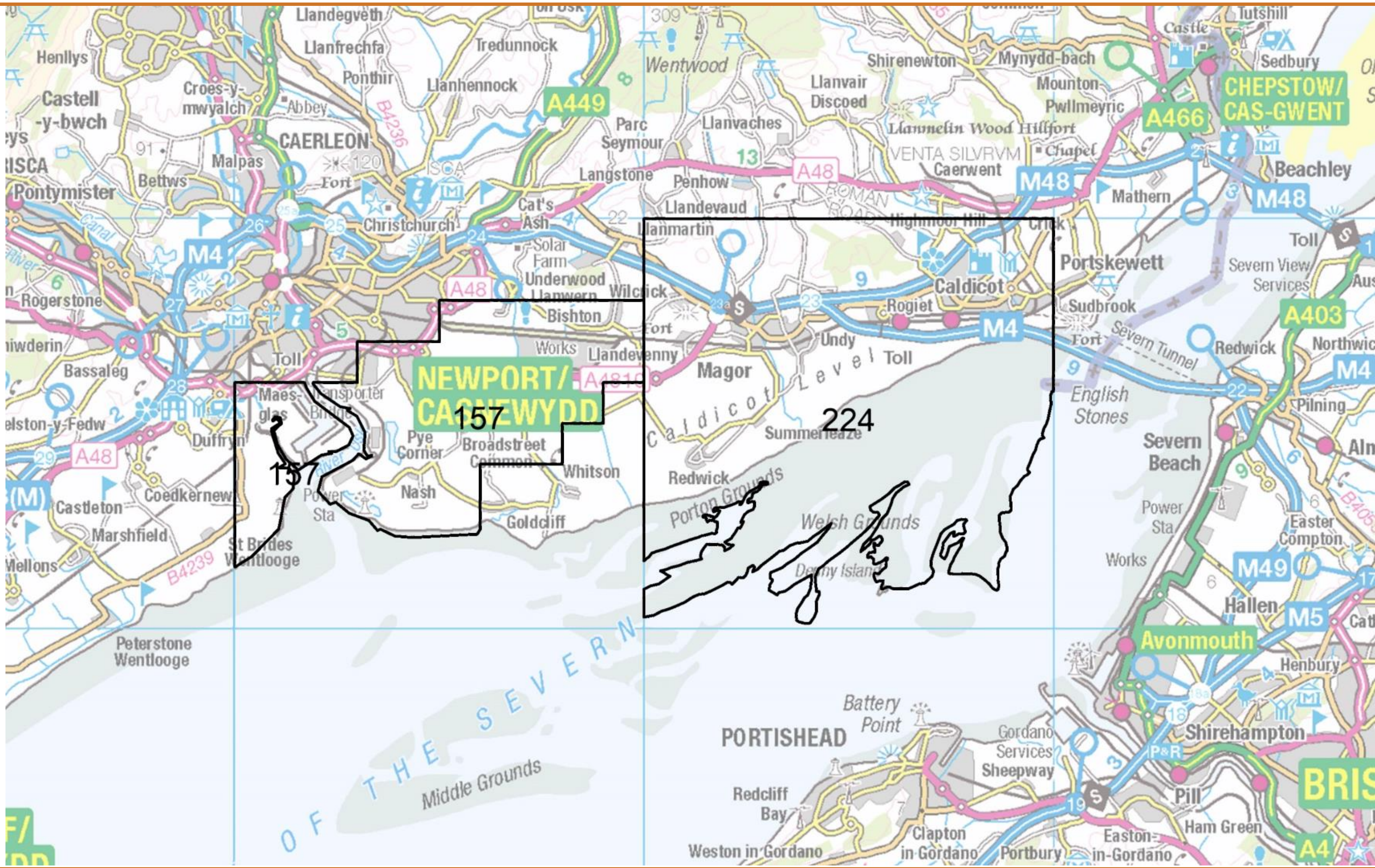
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Rogerstone
Bassaleg
Christchurch
Langstone
Parc Seymour
Penhow
Llandevaud
Llanmartin
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Bishton
Wilcrick
Llandevenny
Magor
Undy
Rogiet
Caldicot
Portskewett
Sudbrook
Mathern
Wentwood
Shirenewton
Mynydd-bach
Mounton
Pwllmeyric
Llanvair Discoed
Llanvaches
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Tutshill
Sedbury
Beachley
Severn View Services
Redwick
Northwick
Pilning
Severn Beach
English Stones
Easter Compton
Hallen
Avonmouth
Henbury
Shirehampton
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Ham Green
Easton-in-Gordano
Portbury
Clapton in Gordano
Weston in Gordano
Redcliff Bay
PORTISHEAD
Battery Point
Gordano Services
Sheepway
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St Brides Wentlooge
Marshfield
Castleton
Coedkernew
Duffryn
Nash
Pye Corner
Broadstreet Common
Whitson
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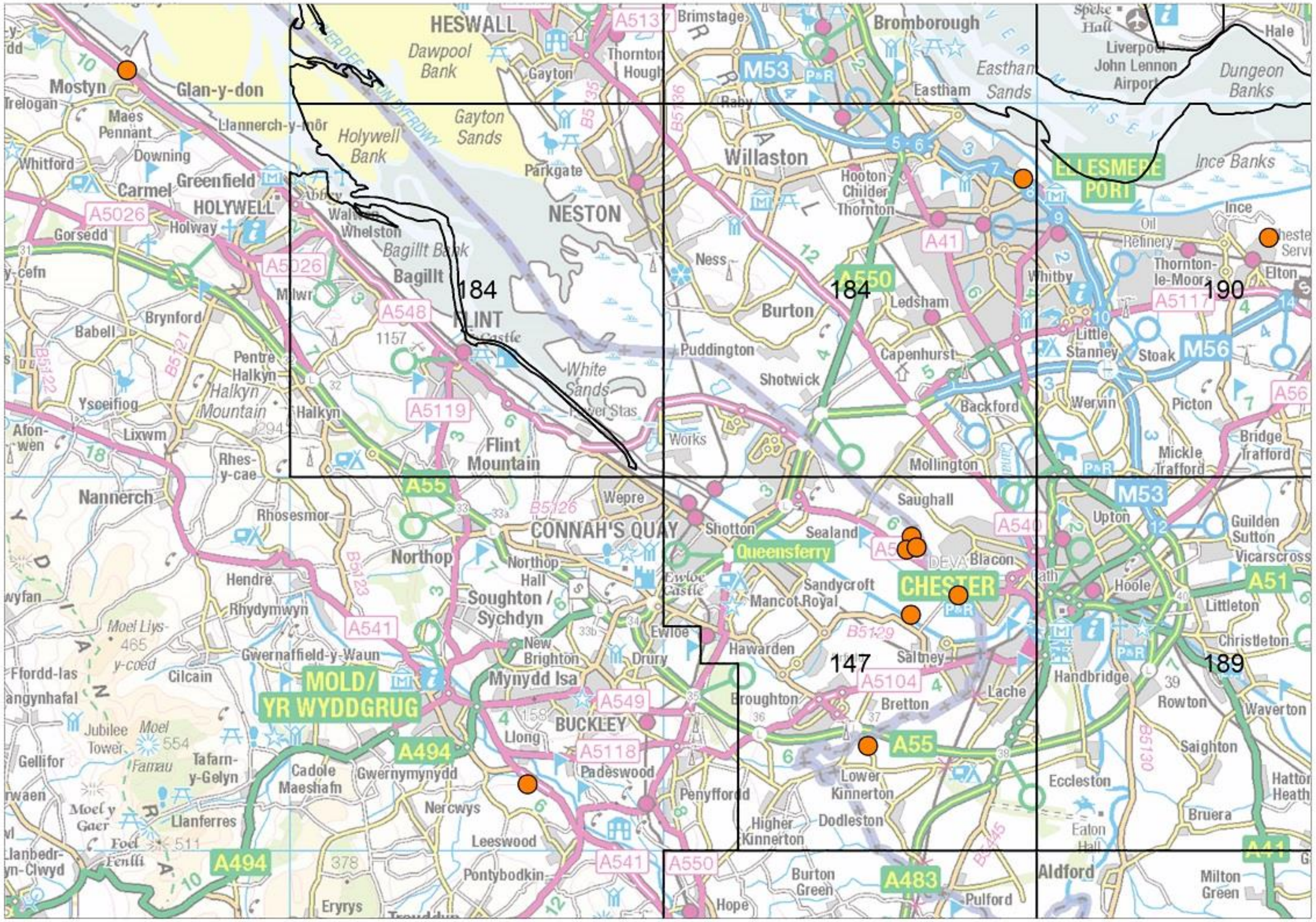

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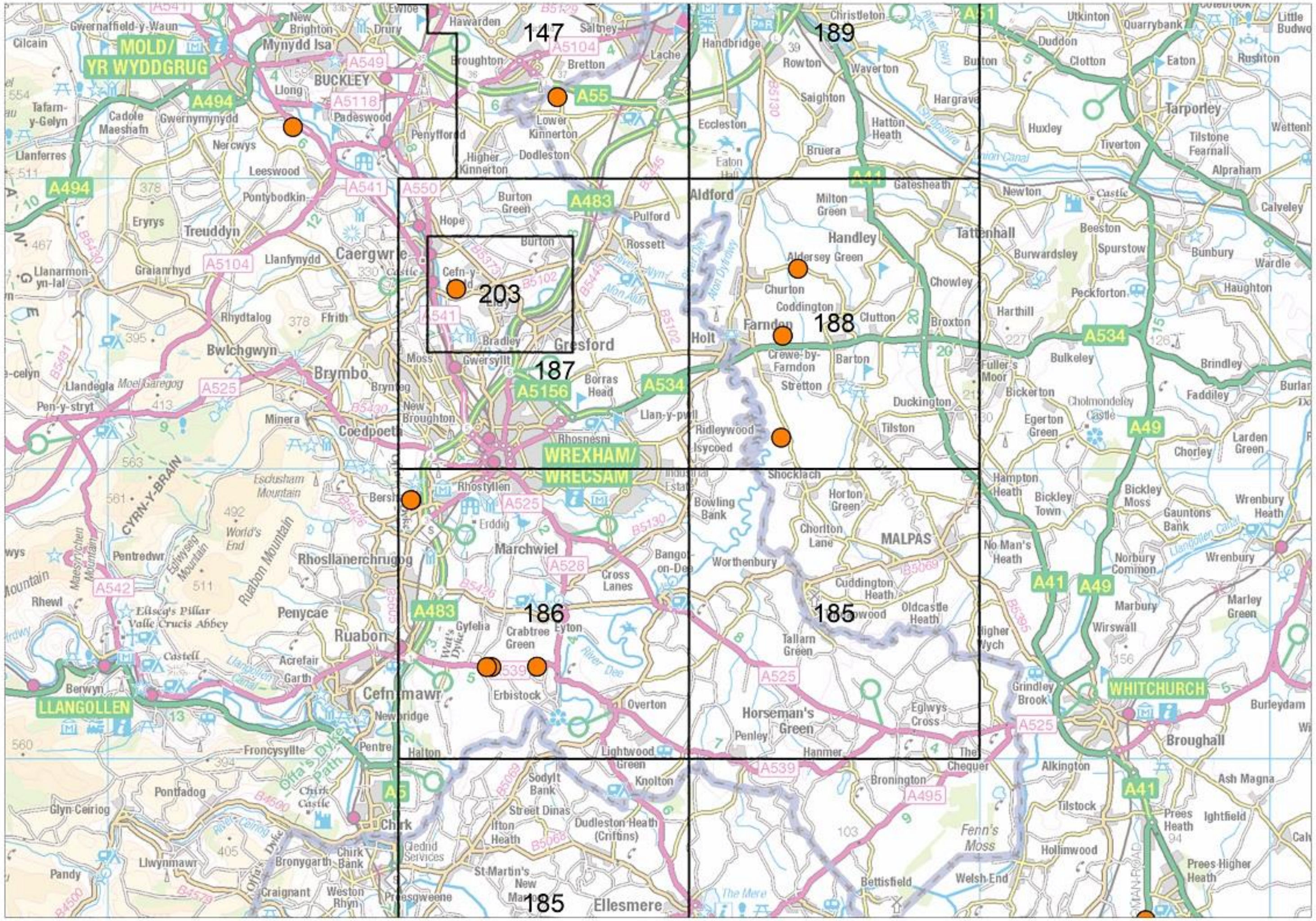
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3.22 Comprehensive regional CBM resource estimates for coalfield areas in Wales have been produced by the BGS (Jones et al., 2004[37]). Table 3.3 presents Jones et al. estimates of CBM resources. Based on analysis of these data, the BGS estimated the potential CBM resource within the South Wales coalfield as almost 290 bcm but was unable to establish a credible figure for the North Wales coalfields. In South Wales, the extent of previous underground workings is likely to be a limiting factor affecting recovery. Jones et al. noted that the North Wales Coalfield was less affected by previous mine workings.

3.23 Petroleum Exploration and Development Licence (PEDL) holders in South Wales include Adamo, Dart Energy, Coastal Oil and Gas, Eden Energy, Sonerex, UK Gas and UK Methane. Within South Wales, one CBM well is planned, nine CBM wells have been granted planning permission and four have already been drilled. Eden Energy and Dart Energy have provided resource estimates. Eden Energy has estimated between 19-38 bcm for CBM and Dart Energy Ltd has reported a resource estimate of between 9 and 21 bcm. The BGS report cites a 10% recovery factor, which if applied to the combined resource estimates gives a CBM reserve estimate of between 3 and 6bcm, which is equivalent to between 4% and 8% of annual UK gas consumption.

Table 3.2 Coal Bed Methane Resource Estimates for Wales

Area	Area (km2)	Average Methane Content (m^3/tonne)	Resource (10^6 cubic metres)
South Wales 1	58.5	20	27,247
South Wales 2	16.8	22.5	6,666
South Wales 3	127.3	17.5	35,007
South Wales 4	244	8.5	55,803
South Wales 5	342.4	14.5	64,546
South Wales 6	290.1	11.5	54,706
South Wales 7	306.6	5.5	45,753
South Wales 8	451.5	Unknown	Unknown
North Wales 1	60.5	8	15,655
North Wales 2	Unknown	8	Unknown
North Wales 3	Unknown	6	Unknown
North Wales 4	Unknown	8	Unknown
North Wales 5	132.5	7.1	Unknown
Anglesey		Unknown	Unknown
Pembrokeshire		<10	Unknown

Based on Jones et al 2004 (Taken from BGS report (2014), A Study of Potential Unconventional Gas Resource in Wales)

[37] Jones, N.S., Holloway, S., Creedy, D.P., Garner, K., Smith, N.J.P., Browne, M.A.E., Duruvan, S. (2004) UK Coal resource for new exploration technologies. Final Report. British Geological Survey Commissioned Report CR/04/015N.

3.24 PEDL holders in North Wales include Biogas, Dart Energy and IGas[38]. Within North Wales, one CBM well is planned, five CBM wells have been granted planning permission and two wells have been drilled to date. IGas's PEDL licence includes the Point of Ayr former colliery site (part of the Flintshire coal seams) which the company has estimated contains a resource of between 31 and 92 bcm of CBM. Applying the BGS cited 10% recovery factor, gives a reserve estimate of CBM in North Wales of between 3 and 9bcm, which is equivalent to between 4% and 11% of annual UK gas consumption. Discussion with the Coal Authority as part of this study indicated that to date, in the UK, CBM tends to be used to generate electricity, which is then fed into the National Grid rather than being used as a source of gas[39].

3.25 Given the potential scale of CBM, both BGS and the Coal Authority commented on the low level of exploratory activity[40]. A possible explanation, suggested by the Coal Authority, concerns the management of the produced waste water arising from exploration and production activity which in CBM overseas (such as Australia) is stored in very large settlement ponds, an option which would not be available to companies in South Wales due to topographical and regulatory constraints. More broadly, the House of Lords report[41] suggested that the 'snail's pace in exploration' (albeit referring to shale gas rather than CBM) "*seem mainly due to uncertainties over regulatory requirements*" although this view seemed more in sympathy with developers than regulators and receiving communities.

3.26 Underground Coal Gasification (UCG) is a process by which air, oxygen and steam are injected into coal seams at depth in order to partially combust the coal. The injectant reacts with the coal and produces heat, hydrogen, carbon monoxide and methane and in some seams, sulphur gases. The mixture of gases which is produced is known as syngas. UCG production is normally achieved by utilising at least two boreholes. The injectant is introduced through one borehole and reacts with the coal which produces heat and syngas which are collected via a separate production well or wells. The Coal Authority is the licensing authority for underground coal gasification. Two companies had licences: Clean Coal Limited (Swansea Bay) and Cluff Energy (Loughor and Dee Estuaries); however Clean Coal Limited had their application for renewal refused in 2013. Cluff have been awarded a five year licence. Little is currently known about the resource for gasification and it is only following exploration and testing activities that resource estimates of underground coal gasification will be possible[42].

3.27 Outside the coalfields, there has been very little exploration for conventional or unconventional hydrocarbon resources in Wales to date. This has led to a paucity of subsurface data against which to evaluate potential resources of shale gas. In consequence, the recent BGS report[43] for Welsh Government concluded that:

[38] IGas acquired Dart Energy in October 2014

[39] Dart Energy's proposed Airth scheme in the Firth of Forth in Scotland, consisting of 14 well sites, is intending to produce gas supplying a distribution facility and connection site, as well as providing gas to the national grid.

[40] Telephone discussion with Rhian Kendall, BGS, 25.9.14 and Simon Cooke, Coal Authority, 10.10.14

[41] House of Lords Economic Affairs Committee (2014) 3rd Report of Session 2013–14, The Economic Impact on UK Energy Policy of Shale Gas and Oil.

[42] Cluff Natural Resources published estimates of exploration target coal tonnage at Point of Ayr on 1 December

[43] BGS (2014) A Study of Potential Unconventional Gas Resource in Wales, Commissioned Report CR/13/142.

> *"there is presently not enough publicly-available data available on the geology, engineering or associated costs of production to make reliable estimates at this stage. Estimates will only be developed with information derived from increased exploration and further research in the future*".

3.28 Further research will be needed including further seismic survey work to understand the depths at which potentially prospective units occur and their possible thickness. Boreholes can also help to confirm rock layer thicknesses, using geophysical logging techniques, supplemented by coring from which rock properties including organic content and mineralogy can be determined. The BGS report highlights that whilst there are similar geological formations to the Bowland-Hodder unit of northern England (in terms of age), without sufficient data, any estimates of a shale gas resource would be highly speculative, open to challenge and certainly subject to future revision.

Factors Influencing Future Extraction within Wales

3.29 The nature and pace of any future exploration and production of unconventional oil and gas in Wales (and more widely in the UK) will reflect differences in geology, changes in regulatory regimes and varying market conditions.

Resource Uncertainties

3.30 In discussion, the BGS highlighted the effects of uncertainty on investor behaviour. Exploration companies can invest regionally/globally and the likelihood that they would choose Wales (even in preference to England) was considered low in the short term, given the amount of up-front investment needed to delineate the scale of the resource/reserve. If substantiated, this view indicates a long term problem as it is only once there is an improved geological and geophysical understanding of the target formations that industry will have greater confidence over whether location in Wales represents an attractive area for investment.

3.31 Whilst the prospects for Wales in the next decade or so may be low, it is likely that exploration activity in the rest of the UK (either through existing onshore licences or as a consequence of the 14th onshore oil and gas round) will provide answers to the viability and consequential scale of the industry. As illustrated below, the timescale for this is medium rather than short term in its nature:

- In evidence to the House of Lords Economic Affairs Committee, the Rt Hon Micheal Fallon MP, former Minister of Energy stated: *"the next stage … is the drilling of … some 20 to 40 exploratory wells over the next couple of years*."
- Peter Atherton of Liberum Capital said in evidence to the Committee: "they [the oil and gas exploration industry] have to drill 20 to 30 wells just to know what the producibility of the Bowland and other UK shale formations are. On the current timetable that is likely to take a very long time; we are into 2020/25."
- Duarte Figueira, of DECCs Office of Unconventional Gas and Oil, also stated in evidence to Committee that the industry: "*would certainly expect production to start before the end of the decade, but to be at scale in the early 2020s.*"

3.32 The recent UKERC report[44] into UK gas security supports a similar timeframe for development but as a note of further caution signals the importance of addressing the gas storage and transmission network over the medium term if the onshore industry is to realise scale:

> *"given the current status of shale gas exploration, it is unlikely that domestic shale gas production will be a factor until the early 2020s and it is also unlikely to be of sufficient scale to significantly reduce the UK's import dependence or to have a significant impact on UK gas prices. In the midstream the focus is upon the need to ensure that the National Transmission System (NTS) is able to respond as the role of gas changes from base load to a back up for renewable intermittency*."

3.33 The initial exploration wells undertaken over the next 5 years will also provide opportunities to address directly issues concerning the public acceptability of hydraulic fracturing and the number of current concerns (including induced seismicity, surface and groundwater quality, water resource availability; treatment of produced water, fugitive emissions, traffic movements, noise and vibration, and visual intrusion). Only when the technologies can be demonstrated to operate safely and with due regard to the environment, will the level of controversy associated with such developments diminish.

Regulatory Regime

3.34 It is the view of DECC, the existing regulators, Public Health England (PHE)[45], Public Health Wales (PHW)[46] and the conclusion of the Strategic Environmental Assessment (SEA) of onshore oil and gas licensing[47] that the application and enforcement of existing regulatory requirements can be expected to ensure that effects of individual exploration activities can be identified, assessed and mitigated to an acceptable level. However, it will not be until the exploration industry has an opportunity to demonstrate that it can undertake these activities in a manner that does not lead to unacceptable adverse effects, that public acceptability of the technologies will be achieved.

3.35 Whilst many commentators state that the UK's regulatory framework is robust, the House of Lords Economic Affairs Committee Report did comment that:

> *"It is also dauntingly complex and untested by large-scale onshore development of shale. Ministers and regulators have taken measures to adapt the system. But many complexities remain, with responsibilities divided between different agencies. Industry is uncertain how the rules would apply in practice. Since the lifting in 2012 of a moratorium on hydraulic fracturing, we understand (May 2014) that the Environment Agency has not received or approved any applications for the necessary permits. There is no reason why effective regulation should not be transparent and speedy as well as rigorous*."

[44] UKERC (2014) The UK's Global Gas Challenge: Research Report, November 2014 http://www.ukerc.ac.uk/support/tiki-index.php

[45] Public Health England (2013) Review of the Potential Public Health Impacts of Exposures to Chemical and Radioactive Pollutants as a Result of Shale Gas Extraction: Draft for Comment, available from http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317140158707

[46] http://www2.nphs.wales.nhs.uk:8080/environmentalphtdocs.nsf/85c50756737f79ac80256f2700534ea3/6eea95e901a4f15080257d88003f5e2a/$FILE/Annual%20Review%202013-14%20FINAL.pdf (page 18)

[47] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/273997/DECC_SEA_Environmental_Report.pdf (page 123)

3.36 The report does recommend that the UK Government should streamline and improve the unwieldy regulatory structure to make it effective as well as rigorous. However, the UK Government's response[48] highlights that a wholesale regulatory change would represent an unacceptable risk of delay and create uncertainty for operators and communities in areas of potential development.

3.37 This response suggests that the current regulatory framework, whilst likely to undergo minor adjustments[49], will largely remain intact for the next few rounds of licensing, and in its own right should not be considered a significant barrier to development. However, this needs to be tested through experience.

3.38 Assuming that industry can then demonstrate the application of proven technologies to known resources, the industry could then reach scale in the later years of the 2020s. This could then create the appetite to explore further in Wales, based on proven technologies and public acceptability of approaches and confidence in the implementation and enforcement of the regulations, particularly if core geological information is available.

Other Considerations

3.39 Mineral rights ownership is clearly defined in the UK under the Petroleum Act 1998, which consolidated a number of earlier pieces of primary legislation, and which vests all rights to the petroleum[50] (oil and gas) resources of Great Britain in the Crown. Petroleum Exploration and Development Licences (PEDLs) are issued by the UK Government to applicants following competitive bidding rounds, where each application is considered against technical, financial and environmental requirements[51]. PEDLs provide exclusivity for an area for defined term periods that reflect the pace of development; however, their award does not exempt the licensee from needing to meet all health and safety, environmental and planning requirements. Licensing also does not confer any priority access rights. This contrasts with the United States, where property rights make the shale gas the property of the landowner, creating a strong financial incentive for private owners to permit shale gas exploration and development.

[48] Government Response to the House of Lords Economic Affairs Select Committee Report (2014) The Economic Impact on UK Energy Policy of Shale Gas and Oil.

[49] See for example, amendments proposed in the Infrastructure Bill, 26th January 2015, http://www.publications.parliament.uk/pa/bills/cbill/2014-2015/0154/amend/pbc1542601m.1481-1487.html

[50] Petroleum is defined in Part I of the Petroleum Act as including "any mineral oil or relative hydrocarbon and natural gas existing in its natural condition in strata; but does not include coal or bituminous shales or other stratified deposits from which oil can be extracted by destructive distillation". However the Crown owns any oil and gas that "exists in its natural condition" in coal strata.

[51] The Government is considering proposals to devolve licensing to Scotland, although this would not be implemented until the next Parliament. Welsh Government Ministers consider that the powers devolved to Scotland for onshore oil and gas matters should be also devolved to Wales.

3.40 Whilst America stands as an example of the huge economic impact that shale gas and oil can have,[52,53] replicating the scale and pace of the US shale oil and gas exploration and production industry appears unlikely in the UK. A report from Chatham House[54] highlights this.

> "*The shale gas revolution of the United States happened because of a coincidence of characteristics. [The main ones include: favourable geology with adequate structural and lithology data; low population densities coincident with major oil and gas plays; government research into fracturing since 1982; 'light touch' federal;[55] and state[56] regulation which exempted hydraulic fracturing from environmental regulations; demand from a growing domestic market; a comprehensive gas transmission network with sufficient capacity to accommodate domestic growth; and a flexible industry able to respond rapidly to the changes in scale.] A key point is that the American 'revolution' in reality happened over a very long period of time – over 20 years – although it was only in the last five years or so that the share of shale gas in domestic production increased significantly. It also happened because of a unique mix of conditions that will be difficult to replicate in the United Kingdom.*"

3.41 In order to respond to the possible growth in onshore exploration and production, the UK oil and gas service industry would need to grow. The current capacity of the UK service industry to undertake onshore shale operations is limited, with few drilling rigs and even fewer units that can hydraulically fracture. In the Barnett shale play in the United States 199 rigs were drilling at the height of operations in 2008, while there were only 34 rigs in all of Western Europe in 2010[57].

3.42 In addition to the supply chain services needed, there is also the need to consider the availability of skilled labour. For many of the skills required, there is a strong degree of commonality with offshore oil and gas, and with the chemicals industry. However, these related industries are already experiencing skills shortages of their own. The 2014 Ernst and Young report[58] noted significant lead times for training. In response to the challenge of skills, the Government, supported by the UK Onshore Operators Group (UKOOG), announced the first National College for Onshore Oil and Gas, headquartered in Blackpool. The new centre will provide training to students ranging from 'A' level equivalence to postgraduate degree level, and will also carry *out research and development for improved equipment, materials and processes that will increase the efficiency and reduce the environmental impact of operations.*

[52] House of Lords Economic Affairs Committee (2014) 3rd Report of Session 2013–14, The Economic Impact on UK Energy Policy of Shale Gas and Oil.

[53] International Energy Agency (2013) World Energy Outlook 2013, page 115.

[54] Paul Stevens, Chatham House (2013), Shale Gas in the United Kingdom, Energy, Environment and Resources 2013/02 http://www.chathamhouse.org/sites/files/chathamhouse/public/Research/Energy,%20Environment%20and%20Development/131213shalegas.pdf

[55] The 2005 Energy Act exempted hydraulic fracturing from being considered an 'underground injection' under the Safe Drinking Water Act – the so-called 'Cheney-Halliburton Loophole'. Compliance with various federal requirements to prevent water contamination was not necessary. Fracturing wastes are exempt from disposal restrictions under the Resource Conservation and Recovery Act.

[56] Groat and Grimshaw (2012), Fact-based regulation for environmental protection in shale gas development, Energy Institute, University of Texas: Austin. http://energy.utexas.edu/images/ei_shale_gas_regulation120215.pdf

[57] Paul Stevens, Chatham House (2013), Shale Gas in the United Kingdom, Energy, Environment and Resources 2013/02 http://www.chathamhouse.org/sites/files/chathamhouse/public/Research/Energy,%20Environment%20and%20Development/131213shalegas.pdf

[58] Ernst and Young (2014), Getting ready for UK shale gas: Supply chain and skills requirements and opportunities.

3.43 When compared to other parts of the world, access to transport networks are unlikely to be the same barrier. However, consented access to water, waste water infrastructure and/or to gas distribution networks may be a constraining factor on development both in Wales and the UK.

3.44 Factors that could increase exploration activity across the UK, including the UK Government's interest in encouraging this activity, could include:

- Energy costs/shocks increasing consumer energy costs and increasing economic viability of onshore exploration and production
- Global political pressures affecting global energy markets creating demand for increased energy security through greater use of indigenous resources.

3.45 However, at this stage, such changes (if or when they are to occur) are highly uncertain. Current low world oil and gas prices provide a particularly weak stimulus to exploration within the UK, although this is a reflection of both weak global demand and new sources of shale gas in particular coming on stream.

3.46 Whilst not able to address market circumstances, the UK government has attempted to provide industry with greater clarity around the long-term tax treatment of shale gas profits by providing a new shale gas field allowance and extending the ring-fence expenditure supplement in order to promote investment[59].

3.47 One company that has recently announced an intention to invest in UK shale gas is Ineos, which is planning to spend £640million in Britain undertaking exploration activities for shale gas. The company has obtained the PEDL for shale gas exploration and development across a 329sq km area around its Grangemouth refinery and petrochemicals plant; however, whilst drilling licences from DECC are held, the company still needs planning permission to proceed. The drive for Ineos to invest in shale gas reflects its intention to move from overseas sources of gas to indigenous ones in order to reduce costs (at present the company is spending £400million per annum shipping liquefied shale gas from the US). In consequence, whilst the announcement is an important indicator of the potential for shale gas in the UK, Ineos's proposals reflect its desire to gain greater cost control over its supply chain rather than a drive to meet UK domestic energy needs and so cannot be considered indicative of wider industry interest at this stage.

3.48 The European Council recently approved the 2030 Framework for Climate and Energy, with the following objectives to be met by 2030:

- A binding EU target of at least 40% reduction of greenhouse gas emissions by 2030, compared to 1990
- A binding target of at least 27% of renewable energy used at EU level
- An energy efficiency increase of at least 27%, to be reviewed by 2020 having in mind an EU level of 30% for 2030.

3.49 There is a fundamental question of whether the growth in shale gas production and use is commensurate with these commitments. The Intergovernmental Panel on Climate Change (IPCC) Working Group 35th Assessment Report identified that using natural gas (including shale gas produced with low-emissions practices) in a modern gas-fired plant would reduce emissions per kWh by half when shifting from the current world-average coal-fired power plant, evaluated using 100-year global warming potentials.

3.50 In consequence, unconventional gas could lower emissions for the transitional period where gas competes with coal. It is the view of the UK Committee on Climate Change that well-regulated

[59] HM Treasury (2013), Budget 2013, March 2013

domestically produced shale gas could have lower lifecycle emissions than the liquefied natural gas that currently comprises a significant part of our gas imports, and would improve the UK's energy sovereignty. However, as the IEA World Energy Outlook 2014 notes:

> *"A critical "sign of stress" is the failure to transform the energy system quickly enough to stem the rise in energy-related CO2 emissions (which grew by one-fifth to 2040) and put the world on a path consistent with a long-term global temperature increase of 2°C. In the central scenario, the entire carbon budget allowed under a 2°C climate trajectory is consumed by 2040, highlighting the need for a comprehensive and ambitious agreement at the COP21 meeting in Paris in 2015."*

3.51 In consequence, if the actual rate of progress towards meeting climate change targets (both international and national) is lower than forecast, and the evidence of climate change continues to grow from a succession of extreme weather events, it is possible that there will be closer scrutiny by governments of the use of fossil fuels including 'transition fuels' such as shale gas. This may influence future energy policy and regulatory frameworks and the future markets for shale gas, affecting the medium to long term prospects for the industry.

Implications for Economic Scenario Development

3.52 Given the uncertainties regarding the scale of the resource within Wales, based on a lack of geological and geophysical data, it is not considered appropriate to propose scenarios for future development based on resource estimates and a modelling of extraction activity. Instead, we have used illustrative scenarios which are indicative of different scales of development consistent with the following scenarios:

- Low - business as usual, with very limited exploration and production activity, focused on CBM activity in the main
- Central - Localised activity in South East and North East Wales, combining both shale gas and CBM
- High - Industry of significant scale in South Wales and North Wales and with considerable additional shale gas resources identified and exploited.

3.53 The precise definition of these scenarios is set out in Section Five, following the review of the economic impact evidence for unconventional oil and gas in Section Four.

4. Review of Socio-economic Impact Evidence

4.1 This section examines the evidence of the economic impact of unconventional gas exploration and production. Whilst the scope includes shale gas, coalbed methane and gasification, it is the former which has been the main focus of the economic literature to date. This is due to the extent to which shale gas has been exploited in the United States over the last two decades, which also explains the majority of the literature being focused on activity which has occurred in the US.

4.2 The section examines first the international evidence which is dominated by the US literature and then examines the evidence from the UK. Each sub-section distinguishes between national economic impacts in terms of wealth and job creation, sectoral and competitiveness effects, prior to considering potential effects on local economies which host the developments.

US Evidence

4.3 Unconventional oil and gas activity has been particularly prominent in the US. As of 2012, there were over 7,700 unconventional gas and 7,200 unconventional oil well completions[60] in the lower 48 US states, producing 36 billion cubic feet (bcf) of unconventional gas and 2 million barrels of oil a day. There are various estimates of the potential expansion of the sector and the production levels over the next two decades and all of these are subject to much uncertainty. IHS for example, estimate that by 2035, US production would be around 80 bcf a day from 11,200 unconventional wells. Similarly for oil it is estimated that in 2035 c. 9,000 wells will be producing 4.5 million barrels per day (mbd).

Economic and Sectoral Impacts

Overall Economic and Employment Growth

4.4 A number of studies have attempted to estimate the overall economic contribution of shale gas activity upon the US economy. The IHS Global Insight study examines the economic contribution of unconventional oil and gas exploitation to the US economy in 2012 and also presents estimates of growth up to 2035. The key conclusions for 2012 include:

- Annual capital expenditure of $87bn, with much of this expenditure sourcing inputs from within the US due to the breadth and depth of the supply chains (in a large part due to the historic importance of the conventional oil and gas sector)
- Supporting around 1.75 million jobs in the lower 48 US states, split between c360,000 direct jobs, c537,000 indirect jobs in supplying industries, and c850,000 induced jobs
- A value-added contribution to gross domestic product (GDP) from upstream unconventional oil and gas activity of around $237bn (around $140k per job supported overall or $262k per direct job which is 126% higher than value for the general economy).

4.5 The same report examines the growth in the unconventional oil and gas sector in the lower 48 States up to 2035 and the potential for this to stimulate additional capital expenditure and to generate higher levels of economic contribution. Whilst there is need for caution here due to the uncertainty attached to the estimates of this nature, IHS concludes that annual capital expenditure will rise to £350bn per year (and accounting for £5.15 trillion in total between 2012

[60] Well Completion is the process of preparing a well, after drilling, for production (IHS, 2012).

and 2035), gross value added per year of £475bn and 3.5 million jobs of which nearly a million are in the supply chain. To put this level of employment in context, it is expected to represent around 2.1% of GDP and 2% of all US workforce in 2035[61].

4.6 The IHS study notes a number of factors which have contributed to the scale of economic and employment impacts besides the actual scale of extraction activity:

- The strength of domestic suppliers, which results in a larger proportion of the expenditure being retained within the US and hence supporting employment in the supply chain in the US. Industries that benefited directly include drilling, extraction, equipment and services used on the production sites. There are also high levels of capital expenditure which benefit the manufacturing and construction industries, as well as industries such as financial and insurance services.
- Many of the jobs, especially in the direct jobs and parts of the supply chain, being relatively well paid.
- The support for a high proportion of induced jobs (around a half in 2012), concentrated in hospitality, consumer goods, educational and medical services, administrative and support services. This is driven by the high average salaries of the workers whose jobs are supported directly or indirectly by the unconventional oil and gas sector.

4.7 Analysis in a review of the US experience of unconventional oil and gas in the US (Albrycht et al. 2012) notes the evidence of strong direct and indirect employment effects. This study also concludes that almost all supply chains for the unconventional oil and gas industry are located within the US and there is very limited import of any products necessary for unconventional gas extraction.

4.8 A number of studies have assessed the potential contribution of lower oil and gas prices arising due to the expansion of unconventional oil and gas production on the US economy and the absolute level and growth of GDP. For example, Spencer et al (2014)[62] conclude that '*its short-term stimulus effects at 0.88% of GDP during the 2007/8 to 2012 downturn*' and that '*the unconventional oil and gas revolution has also had a minimal impact on US manufacturing, confined to gas-intensive sectors, which we calculate as making up about 1.2% of US GDP. There is thus no evidence that shale gas is driving an overall manufacturing renaissance in the US*'. The study also estimates the average increase in the level of US GDP that is likely to occur between 2014 and 2040 as a result of greater productivity from lower gas costs[63]. The average increase in the level of GDP between 2014 and 2040 is estimated to be in the order of 0.575% of GDP

Employment Impacts across the Unconventional Oil and Gas Plays

4.9 A number of the major unconventional oil and gas plays in the US have been the focus of economic impact studies. A selection of the findings are summarised below.

4.10 The Eagle Ford Shale is one of the largest plays in the US. Overall, oil and condensate production in the Eagle Ford has grown from 581 barrels per day in 2008 to over 1.1 million barrels per day in 2014. Natural gas production now topped 4 billion cubic feet per day in 2014. The University

[61] IHS Global Insight projections.

[62] Spencer et al. (2014) *Unconventional wisdom, an economic analysis of US shale gas and implications for the EU.*

[63] This is done using forecasts for average EU gas prices to set the baseline for the US prices in the absence of shale gas, and comparing them with the EIA forecasts for US industrial gas prices. Furthermore, GDP growth projections of 3% per annum are used until 2025, followed by a slowdown growth of 1.5% until 2040. Finally, it is assumed that 90% of the decline in natural gas costs are translated into cheaper product prices of intermediate and final goods.

of Texas[64] estimate that for a defined area of Texas consisting of 21-counties in 2013 (which includes the 15 largest producing counties and 6 surrounding counties), over $87 billion in economic output (and $48 billion in gross regional product) and nearly 155,000 full time equivalent jobs were supported (c9% of the overall IHS employment estimate for the US lower 48 States). A greater proportion of these jobs were accounted for by direct and indirect (supply chain) employment, due to the leakage of consumer expenditure out of the State (33% were direct and 46% were indirect). The study predicts around a 60% increase in economic output between 2013 and 2023.

4.11 The Marcellus Shale in the US also spreads across several states, including Pennsylvania, West Virginia, New York and parts of Ohio. An assessment of the economic impact of unconventional oil and gas plays in Pennsylvania State[65] where 710 wells were drilled in 2009, estimated that around of 22,000 full time equivalent (FTE) direct jobs were supported across all sectors, with around 3,000 (14%) in the Mining Sector and 5,000 in the Construction Sector (23%). This activity also supported 8,700 indirect jobs and a further 13,600 induced through the spending of wages and salaries.

4.12 The analysis of Marcellus Shale industry in Pennsylvania by Cornell University[66] concluded that the drilling phase accounted for over 98% of the natural gas industry workforce at the drilling site and a very high proportion of lifecycle employment, which then fell off rapidly during the production phase. Where the expansion of drilling activity is substantial, large numbers of workers are attracted into an area as the local population typically lack the relevant skills. The authors note that this new population can leave just as quickly as it grew, where the productivity of the wells or changes in other factors make the play uneconomic.

4.13 The production phase employment accounts for less than 5% of the lifecycle workforce, but tends to be more predictable in its nature over the production phase and offering more opportunity for access by local residents given the skills required and opportunities for on the job training. The authors note that 'o*ccupations associated with the production phase tend to be less labor intensive, more location specific, less hazardous, and more specialized than development phase occupations, while still providing excellent wages and benefits'.*

4.14 Table 4.1 summarises the findings with respect to employment supported by shale gas development across several US studies of the Marcellus Shale.

[64] University of Texas (2014) Economic impact of the Eagle shale drilling.

[65] Considine, Watson and Blumsack (2010) The Economic Impacts of the Pennsylvania Marcellus Shale Natural Gas Play: An Update.

[66] Cornell University (2011) Workforce Development Challenges in the Natural Gas Industry.

Table 4.1 Summary of Employment Contributions by Shale Gas Plays

	Eagle Ford Shale*	Marcellus Shale**	Bakken***
Total Employment (per well)	47		
Direct	16	9-13	13-15
Indirect	21	19	
Induced	10		

Sources:
*University of Texas (2014)
**MSETC (2009) and Pennsylvania Economy League (2008) estimates
***North Dakota Department of Mineral Resources

Comparative Studies of Regional Economic Performance

4.16 A number of studies have sought to identify the economic contribution of unconventional oil and gas to regional economic performance by examining the comparative performance of areas with and without this development.

4.17 Spencer et al. (2014) compared the change in employment prospects across US states with differing levels of oil and gas production and found a weak positive correlation between unconventional hydro-carbon production and overall employment growth.

4.18 Weber (2012)[67] undertook an ex post analysis of the effect natural gas production has on overall job levels within all counties in the states of Colorado, Texas and Wyoming. The study focused on the jobs created in the county where the production occurs, ignoring jobs created in other counties through the supply chain or the leakage of personal expenditure. The authors found that:

- Being a producing county was associated with higher growth in total employment (1.5%) and income (2.6%), but the overall estimates of employment supported were much smaller than most ex-ante assessments
- $1 million in gas production (at wellhead prices) generated an absolute number of 2.35 jobs within the county
- During the period 1999 to 2007 the rapid growth in gas industry was responsible for adding on average 1,780 more jobs to county economies
- Furthermore, the findings show that the increases in household income went to households in the upper half of the income distribution.

4.19 The reasons for the lower estimates of employment impact found in this study were cited by the authors as being in part due to: (i) the focus on within county employment creation and support; (ii) not including all employment associated with the exploration, production and decommissioning lifecycle.

4.20 A more recent study by Weinstein (2014)[68] examined employment creation and local labour market restructuring during the shale industry expansion in the US found that shale producing counties experienced a 1.3% increase in employment associated with this activity, whilst the growth in earnings was higher at 2.6%. Non-producing bordering counties were also found to benefit from spatial spillover effects, with a 0.4% increase in employment and a 0.8% annual boost in earnings.

[67] Weber (2012) The effects of a natural gas boom on employment and income in Colorado, Texas, and Wyoming.

[68] Weinstein (2014) Local Labor Market Restructuring in the Shale Boom.

Other National Impacts

Energy Security

4.21 Development of unconventional gas can have a significant impact on energy security. Over the last 40 years the US has consistently been a net gas importer. However, from 2007 to 2012 the net imports have fallen by 55% and by 2020 the US is expected to become a net gas exporter[69].

Energy prices: gas and electricity

4.22 The unconventional energy revolution in the US has put downward pressure on energy prices for the US consumers. Wellhead prices for US natural gas were trading at around $4 Mbtu in late 2013, a sharp drop from $8 Mbtu prior to 2008[70]. Furthermore, a widening gap has occurred between natural gas and crude oil prices, encouraging a shift towards gas as a transport fuel.

4.23 Lower natural gas prices also translate into a reduction in electricity prices, although the impact for consumers has been less dramatic than that which has occurred in the wholesale gas market for electricity generators. The regions in the US with the highest natural gas extraction have the lowest electricity price and vice versa[71]. This is a particularly important factor for energy-intensive businesses.

Price of chemicals

4.24 The IHS report (2013)[72] notes that the impurities from natural gas can be extracted to produce ethane, butane and propane, which are valuable materials in the petrochemical industry. For petrochemicals and fertilizer producers, feedstocks account for up to 90% of the production costs. Lower natural gas prices for both industrial use and electricity generation, and higher supply and a fall in production costs for feedstock such as ethylene, could benefit the entire value chain.

4.25 Unconventional gas-derived feedstock is also cheaper than oil-based feedstock, which has attracted domestic capital investments driven by these lower prices. In fact, there are a number of projects planned or underway including natural gas processing plants, fractionation capacity projects, ethane and propane projects for fertilizers etc[73].

4.26 The IHS (2013) report also estimated that in 2012 employment in energy-related chemicals was more than 53,000 jobs, estimated to increase to almost 319,000 jobs by 2025. Combined with the total unconventional oil and gas value chain employment, this represented around 2% of the total US employment in the short term (2012-2015), with the potential to increase to 2.4% by 2025.

[69] IHS (2012) America's new energy future: the unconventional oil and gas revolution in the US economy. Volume 1.

[70] Spencer et al. (2014) Unconventional wisdom, an economic analysis of US shale gas and implications for the EU.

[71] Albrycht (2012) The impact of shale gas extraction on the socio-economic development of regions – an American success story and potential opportunities for Poland.

[72] IHS (2013) America's new energy future: the unconventional oil and gas revolution in the US economy. Volume 3.

[73] University of Texas (2014) Economic impact of the Eagle shale drilling.

Infrastructure

4.27 Extraction of unconventional gas requires a significant water resource: a single shale gas well with one lateral could require between 1,500 and 45,000[74] cubic metres of water depending on complexity of the shale and the amount of times it gets fractured. Availability of such water supply has been a challenge in the region of Eagle Ford Shale due to drought in the area, which had been having an impact with or without hydraulic fracturing. To resolve the issue, the Texas State water authorities are providing incentives for technology development in water infrastructure as well as waste-avoidance and new sources of drinking water[75].

4.28 The use of fresh water for hydraulic fracturing in turn creates between 30-70% of flowback water which returns to the surface and has to be treated. In North America the treatment and disposal of waste water in particular has been a concern. For example, in New York the environmental authority sees the absence of viable disposal options as an incentive for improper disposal, potentially leading to spills and contamination. In Garfield County in Colorado there were a total of 1,549 spills recorded between 2003-2008, with 20% of them resulting in water contamination[76]. The Cornell University (2011)[77] study points out that drilling and production of unconventional oil and gas can have a significant effect on local infrastructure: while access roads to well sites are being created and maintained by operators, many of the journeys made by trucks will be on public roads, some of which are not designed to withstand the volume or weight of this level of traffic.

Research & Development

4.29 Hydraulic fracturing has spurred innovation in other related areas, such as water treatment, which has seen a large increase in patent activity following the surge in shale gas production. Most active companies in this area are oil and gas companies and the larger service providers. However, individuals have also made a sizeable contribution. While large companies account for around half the patents, SMEs have accounted for 36% in the last 5 years[78].

Local Impacts

Workforce Requirements, Training and Education

4.30 Studies show that the drilling phase of shale gas development usually depends on an out-of-state workforce, except for truck hauliers and construction jobs[79]. This is especially the case where the shale plays are more complex and require higher technological advancements and labour intensity. The energy companies and contractors that perform this type of drilling are mostly national or international in size, limiting the direct job opportunities for locals. Various studies have pointed to the mobile nature of the capital equipment and workforce required during the exploration and drilling phase. The study by Cornell University[80] of the Marcellus Shale

[74] New York City Department of Environmental Protection (2009) Impact Assessment of Natural Gas Production in the New York City Water Supply Watershed.

[75] University of Texas (2014) Economic impact of the Eagle shale drilling.

[76] Colorado Oil and Gas Conservation Commission (2007) Colorado Oil and Gas Industry Spills

[77] Cornell University (2011) Economic consequences of shale gas drilling.

[78] IHS (2013) America's new energy future: the unconventional oil and gas revolution in the US economy. Volume 3.

[79] Cornell University (2011) Economic consequences of shale gas drilling.

[80] Marcellus Shale Education & Training Center (2009) Marcellus Shale Workforce Needs Assessment.

in Pennsylvania found that where exploration and drilling occurs at scale and over a prolonged period in particular locations, there are opportunities to replace some of the specialist 'out-of-town' workers with local employees if they are available or appropriate training is provided. With time, local businesses who have possibly been part of the conventional oil and gas supply chains, are able to adapt their activities to be able to take part in shale gas development.

4.31 There are proportionately more employment opportunities for local residents during the post-drilling production phase, where it is generally more cost effective to recruit and as necessary train local workers. Whilst these jobs can be as highly skilled as those during the exploration and drilling phase, they are more generally available in local labour markets.

4.32 The extent to which the local workforce can benefit from unconventional gas activity in the area largely depends on the workers possessing the requisite skills. Otherwise the workforce would have to come from outside the area, at least initially. In the Eagle Ford Shale region, for example, despite the fact that the oil and gas has been established in Texas for decades, the increased activity from the development of unconventional gas industry has led to a shortage of labour among the local workforce, across a range of occupations. Several training schemes have been put in place, with universities and colleges across Texas developing new training programs[81].

4.33 In Colorado, the unconventional oil and gas industry has established partnerships with local universities and colleges. Exxon Mobil and General Electric have worked with the Colorado School of Mines to develop a program on unconventional oil and gas regulatory practices, and the Engines and Energy Conversion Laboratory at Colorado State University is designing and testing natural gas engines. These programs aim to retain and maximise the economic benefits from the oil and gas industry in Colorado so that the local workforce develops skills to take up direct industry jobs and opportunities within the supply chain.

4.34 In Ohio, while shale development is still at an early stage, additional training is being developed in haulage, welding, mechanical engineering and oil field safety and orientation, with the primary purpose of providing local residents with access to employment opportunities. There are also workshops being hosted for potential suppliers in order to introduce them to regulatory standards, culture and operating practices to help them win contracts and to invest in the skills that operators are seeking. Furthermore, Ohio universities are working with the industry to research topics such as new materials and environmental protection measures.

Impact on Local Sectors

4.35 Various studies have explored the expenditure impacts on sectors at a more local level, including service sectors such as retail and hospitality. The Cornell University (2011)[82] study found that this boost to local service sectors through increased expenditure could lead to upward pressure on prices and the potential displacement of existing customers. This was particularly the case for short term accommodation in the area, such as hotels, motels etc. As demand for goods and services increases, prices go up, especially for short-term accommodation, where there was limited scope to increase supply, at least in the short term.

4.36 The same study notes the potential for negative wider economic impacts through price and labour substitution effects. This arises through the increase in the price of some factors of production (including labour) facing local businesses not in the oil and gas sector, as well as the loss of workers to operators in the oil and gas sector and its supply chain. The authors argue

[81] University of Texas (2014) Economic impact of the Eagle shale drilling.

[82] Cornell University (2011) Economic consequences of shale gas drilling.

that this could lead to local businesses closing or choosing to leave the area, making the local economy more dependent on drilling activities and less diverse in the long run.

4.37 However, there are some underlying factors which determine the extent of this effect. It appears that it is the larger and more established towns and diversified communities that attract the big influx of out-of-town workers, even if there are rural and isolated areas closer to the wells[83]. In fact, construction workers related to the initial stages of drilling are more likely to take longer commutes, whereas the longer term workers are the ones more likely to choose to reside in close proximity to the wells.

Impact on Tourism

4.38 One Cornell University study focused particularly on the effects of production activity within the Marcellus Shale on tourism-facing sectors[84]. An influx of out of town workers was found to increase demand for accommodation. In Pennsylvania, hotel occupancy rates had soared to over 95% despite a nationwide recession. The studies found that in the states of New York and Pennsylvania there has been a particular shortage of short-term accommodation during festivals and sports events.

4.39 Another potential impact on the tourism sector arising as a consequence of unconventional gas development is the visual impact. These effects are fairly localised to drilling sites. Drilling rigs can reach heights of 150 feet or more, and during production rigs are operating 24 hours a day creating night time visual impacts through flaring and rig lighting. From a distance of more than 0.5 miles however, drilling sites become difficult to see, and have a low overall impact which can be compared to cell phone towers or wind turbines[85].

4.40 One of the concerns regarding the effect of gas drilling on tourism is the effect of truck movements directly impacting visitors (and residents). Truck traffic peaks during drilling and hydraulic fracturing operations, lasting 24 hours a day for 2-3 weeks. In New York State for example, truck movements had amounted to between 890 and 1,340 per well, not including support vehicles, equipment transportation and automobile traffic[86]. This has been one of the more significant impacts in the US due to its least localised nature and interfering with citizens and visitors due to shared infrastructure.

4.41 Finally, anecdotal evidence cited in a number of reports has pointed to the increase in employment opportunities for local workers as a consequence of the stimulus provided by drilling, leading to shortages in sectors with harder to fill jobs such as tourism.

Local public services

4.42 The presence of unconventional gas exploration in an area could cause a strain on public services. Firstly, the increased volume of traffic and presence of trucks carrying heavy loads on local roads creates a greater need for policing through the need to control truck volume and weight limits[87].

[83] University of Texas (2014) Economic impact of the Eagle shale drilling.

[84] Cornell University (2011) Drilling in Marcellus Shale. Potential impacts on the tourism economy.

[85] See reference 87

[86] See reference 87

[87] Cornell University (2011) Economic consequences of shale gas drilling

4.43 Furthermore, the influx of workers creates a strain on local schools and hospitals, and increased costs for local governments, both in the short and in the long term. As the demand for new services or increased levels of service is created, administrative capacity, staffing levels, equipment and outside expertise are needed, and often have not been budgeted for. A study of Sublette County[88], a rural county in Wyoming, shows that as a result of oil and gas industry development in the area, the permanent population (ie excluding transient workers) had increased by 34% between 2000 and 2007. At the same time, the ambulance runs, medical visits, court cases, arrests and reported crimes had increased rapidly reflecting the impact from new and transient workers.

4.44 The IHS (2012) report estimates that in 2012 state and local tax receipts arising from unconventional oil and gas activity amounted to an estimated $31 billion. This represented 5% of US lower 48 States' total expenditures and 41% of the estimated 2012 budget gaps.

4.45 However, as noted above by Jacquet, while local governments may experience increases in revenue, there are also significant expenditures required to sustain the public infrastructure and services which experience an increase in demand and other potential wider costs of unconventional gas and oil exploitation.

Economic Impacts of Coalbed Methane

4.46 Coalbed methane development in the US is far less widespread than shale gas. An early study by EPA (1994)[89] estimated the potential of coalbed methane development in the Appalachian region[90] in the US. Using production scenarios of between 210 and 270 billion cubic feet (bcf) by 2010, the study estimated direct employment of around 2,500 jobs and indirect employment of 5,000 jobs. The underlying assumptions are that a vertical well development would require c20 people per bcf directly over the first two years, while the vertical well production would only need 6 people per bcf per year.

4.47 The employment was forecast to occur in the states where most of the production takes place, namely Pennsylvania and West Virginia. The sectoral impacts are expected to mainly occur within mining. There is no readily available ex-post evidence to confirm how accurate these estimates were.

4.48 A report by Harvey Economics (2012)[91] estimates the employment benefits of CBM in Las Animas County, Colorado. CBM industry related direct employment in the county was 579 jobs, and a total employment of 1,507 had been achieved. This represents around 18% of total employment in the county, with average annual wages double the county average level.

4.49 A study of CBM development in Alberta Canada, suggests that the resulting economic impacts will not only affect Alberta, but also Canada and even US states outside of Canada. This is due to the fact that some goods and services needed for drilling and production will need to be supplied from outside Alberta. The study estimates the total impact on Canada's GDP of the HC CBM development as a cumulative figure from 2006-2064, which in total would account for 13-16.2% of Canada's 2004 GDP level. The extent to which this would happen depends on the number of

[88] Jacquet (2009) Energy Boomtowns and Natural Gas: Implications for Marcellus Shale Local Governments and Rural Communities.

[89] EPA(1994) The environmental and economic benefits of coalbed methane development in the Appalachian region.

[90] covering the states of Ohio, Pennsylvania, Virginia and West Virginia

[91] Harvey Economics (2012) Fiscal and economic benefits of coal bed methane extraction and water production in Las Animas county.

wells drilled each year and the price level of natural gas. Of the total impacts on Canada's GDP, 17-21% will come from construction and the remaining 79-83% are related to natural gas production from the play. It is also estimated that the GDP impact on Alberta would account for 89-91% of the total GDP impacts generated by the CBM industry development, with 4-5% occurring in Canada and the remaining 5-6% leaking outside of Canada[92]. Again, there is no readily available ex-post evidence to confirm how accurate these estimates were.

4.50 The same study shows that economies outside Alberta would benefit more from the investment (construction) activities stage rather than the production stage, since investment activities require more imported goods and services. In terms of sectors, the development of CBM would increase the value of the natural gas industry the most, accounting for around two thirds of the total GDP impact that would arise. This is due to the fact that investment and value of production are accounted for in this sector. Other industries benefitting would be within finance, insurance and real estate, manufacturing, business services, food and accommodation.

4.51 The estimated employment impact from CBM in Alberta during the construction and production period between 2006 and 2017 would suport 28-29,000 FTE jobs per year in total in Alberta, Canada and outside of Canada. Over the following production period between 2018 and 2064 it is estimated that 6-7,000 FTE jobs would be generated. These impacts are based on the underlying assumptions that between 2,500 and 5,000 CBM wells would be drilled per year and a range of likely gas prices was taken into account. Overall, considering cumulative effects between 2006 and 2064, it is estimated that around 40% of jobs would be created by the construction phase and the rest would be related to production[93].

4.52 It is difficult to draw a direct comparison between shale gas and coalbed methane in terms economic impact due to a lack of robust evidence on coalbed methane and the difference in the intensity of the processes. A rough comparison of available evidence suggests that 20 FTE jobs are generated per 1bcf during CBM well development (EPA, 1994) – this compares to c.15FTE jobs per bcf[94] for a shale gas well. However, the development of a coalbed methane well requires significantly less expenditure: c. $200,000 capex[95] per CBM well compared to c.$6.4m[96] per shale gas well, and produces less natural gas: a CBM well produces between 0.16-0.4bcf[97] of gas per well, whereas a shale gas well produces between 2-3bcf over its lifetime. This implies that production per single shale gas well corresponds to 8-12 CBM wells.

UK Economic Impact Evidence

4.53 Given the limited shale gas and coalbed methane exploration and production activity which has occurred to date in the UK, all of the available studies are ex-ante in their nature. Many of these studies are national in their focus, being undertaken by DECC, BIS or UKOOG (the onshore oil and gas industry body), applying the US experience to the UK. A number of ex-ante regional or local assessments have also been undertaken by developers with an interest in the potential plays in these areas, including Cuadrilla and iGas. As is the case in the US and elsewhere, there is far less evidence about the potential impact of CBM.

[92] Canadian Energy Institute (2006) CBM development in Alberta.

[93] See reference 95

[94] A calculation based on IHS (2012) figures on annual production and employment.

[95] The Economics of Powder River Basin Coalbed Methane Development)

[96] An average based on IHS(2012) estimates.

[97] Swindell (2007) Powder River Basin Coalbed Methane Wells-Reserves and Rates.

4.54 Each of these studies are examined in more detail here, as they provide an important reference source which informs the assessment in this study. A number of the headline assumptions and impacts are summarised in Table 4.2 at the end of the section.

National Shale Gas Studies

4.55 Prior to the launch of the 14th licensing round for conventional and unconventional oil and gas in 2014, DECC undertook a Strategic Environmental Assessment[98] of this potential activity. The licences could cover: conventional oil and gas exploration and production; unconventional oil and gas exploration and production (shale oil and gas, virgin coalbed methane); and natural gas storage in hydrocarbon reservoirs. Consideration was given to all the stages in the oil and gas production and development lifecycle, under high and low activity scenarios for unconventional oil and gas[99] (including shale and CBM).

4.56 The assessment estimated that for the high activity scenario peak, after the effects of leakage have been taken into account, a total of between 16,000 to 32,000 FTE jobs could be created which would represent an increase of between 3.5% and 7% in the level of employment supported by the UK oil and gas industry sector[100]. However, the assessment notes that the potential for these jobs to directly benefit those local communities in which sites are located would depend on the balance between skilled and unskilled construction and oil and gas posts required and the availability of individuals in the local labour market with the required skills and relevant experience.

4.57 The assessment identified that under the United Kingdom Onshore Operators' Group (UKOOG) (2013) Community Engagement Charter, benefits from shale gas exploration and production would be provided to host local communities and county/unitary authorities in the form of an initial community contribution of £100,000 per well pad where hydraulic fracturing takes place. Under the high activity scenario, total UK contributions could be between £3 and £12 million. During production, it is estimated that community benefits to the value of 1% of revenue from production could amount to a total of £2.4 million to £4.8 million per site (equivalent to between £0.3 billion and £0.6 billion across all sites) under the high activity scenario, assuming each well is productive for 20 years.

4.58 The assessment also considered a range of environmental impacts with a selection of the impacts highlighted below:

- The assessment estimated that flowback (the fracturing fluid injected into the shale rock during hydraulic fracturing which returns to the surface) could range from 3,000 cubic metres to 18,750 cubic metres of water per well. Under the high activity scenario, this could mean that up to 108 million cubic metres of wastewater would require treatment. Depending on where the wastewater is treated, the additional volume could place a significant burden on existing wastewater treatment infrastructure capacity, and require further or new investment. However, if on-site treatment and recycling could occur, wastewater volumes (and associated vehicle movements) could be reduced.
- On the conservative assumption that each well is re-fracked once in its lifetime, total water consumption associated with hydraulic fracturing could be between 57.6 million

[98] DECC(2013) Strategic Environmental Assessment for Further Onshore Oil and Gas Licensing

[99] The high activity scenario envisaged a total of between 1,440 and 2,880 wells being developed from 120 well pads with a peak number of 180 to 360 wells per annum being drilled and subject to hydraulic fracturing; the low scenario assumes a maximum of 360 wells from 30 pads.

[100] Oil and Gas UK (2012) 2012 Economic Report, http://www.oilandgasuk.co.uk/cmsfiles/modules/publications/pdfs/EC029.pdf

to 144 million cubic metres under the high activity scenario. On that scenario, annual water use could be up to 9 million cubic metres, which would be approximately 18% of the 48.5 million cubic metres of mains water presently supplied to the energy, water and waste sectors annually. The potential impacts that this could have on, for example, water resource availability, aquatic habitats and ecosystems and water quality is, however, more uncertain. Water would typically be sourced from a mains water supply which would need agreement from the relevant water company, or could be abstracted from groundwater or surface water which would need an abstraction licence; in either case, any addition to demand would only be granted where assessed by the regulator as sustainable. Demand could however be substantially reduced if it could be met from recycling and reuse of flowback water.

- Other effects from exploration and production of shale oil and gas with the potential to be significant under the high activity scenario were also identified in respect of land use, geology and soils, air, resource use and landscape.

4.59 The assessment identified that there are further negative effects identified due to noise, dust, vibrations during construction and the substantial vehicle movements that could impact on local communities and their health.

4.60 The likely effects identified are generally expected to occur in the development and production phases, and it is noteworthy that the industry is not expected to be at substantial scale before the 2020s. This would allow time for any necessary new investment in infrastructure such as waste water treatment capacity. The assessment concluded that '*the application and enforcement of existing regulatory requirements can be expected to ensure that effects at the project level will be identified, assessed and mitigated to an acceptable level*.'

4.61 The Institute of Director's report, Getting Shale Gas Working (2013), is one of the first comprehensive assessments of the potential economic impacts of shale gas development in the UK. It used two development scenarios as a base:

- A single pad of 10 wells and 10 laterals (i.e. one lateral per well) which could support 400 FTE jobs
- A pad of 10 wells and 40 laterals (i.e. an average of four laterals per well) which could support just over 1000 FTE jobs.

4.62 The higher scenario is arguably an optimistic assumption in that there is no evidence yet from US that this intensity of activity could be achieved – to date, the mid 20s for wells per pad is the upper end of what could be achieved (AEA 2012 report for the EC '*Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing*' noted up to 20 wells per pad based on a 2011 US Department of Energy report).

4.63 In the case of widespread development where the UK would accommodate for 100 pads of 10 wells and 40 laterals, the total jobs created by the industry (including direct, indirect and induced effects) would amount to 74,000 jobs at peak production time, although this estimate is based on an assumption that there is no leakage of expenditure out of the UK (which reflects an underlying view that the sector and the related supply chain and skills base could develop quickly in response to the growth in exploration, drilling and production).

4.64 The study also estimates that in the case of the widespread development scenario, UK gas import dependency could go down to 46% and potentially as low as 27% under the high production scenario. This is compared to the scenario of no or very limited shale gas by 2030, where import dependency would amount to 63%.

4.65 Additionally, the report outlines the potential for the UK to benefit from reduced gas prices, as well as reduced prices for petrochemical feedstocks as a result of shale gas development. However, it points out that it is too early to say how significant these effects would be, in a large part attributed to the general uncertainty around future gas prices.

4.66 The IoD report highlights a number of key recommendations for development of unconventional gas industry in the UK:

- It emphasizes that developments take time to gain scale, as years of research and development could be required, but shale gas development can provide an important boost in a well-diversified economy like the UK, and so the benefits could be significant. These could include well-paid jobs, tax revenue, development of local supply chain and a contribution to the balance of payments as well as an opportunity to strengthen the heavy industry through increased provision of feedstocks to the chemical industry, obtained from domestic oil and gas production.
- Domestic natural gas production could lead to environmental gains in several ways, including through displacement of coal. Gas is also an effective back-up power source for renewables such as wind and solar, and the US example shows it has potential as a transport fuel, which provides air quality gains.
- If the resource of natural gas seems substantial, infrastructure, such as pipelines and gathering stations, can be built and specialist equipment, such as drilling rigs, can be produced.
- It will be essential to establish a stable tax regime for the industry, which requires changes and more certainty in order to safeguard investment and production. Recent changes have included certainty on decommissioning relief and expanding field allowance to aid industry recovery in the North Sea from damaging tax rises in 2011.
- Partnerships and cooperation between sectors will be a vital part in attracting investment, improving skills and managing safety. For example, the development of partnerships can set environmental standards for drilling while maintaining the economic opportunities from production. The cooperation between local government bodies with local organisations can help developing initiatives for training, supply chain and innovation.
- Finally, the report notes that local communities faced with shale gas development are concerned about its potential impacts upon the local environment and that these concerns need to be addressed. It notes that an information campaign explaining the importance of development and the measures that will be put in place to protect the environment and local quality of life, as well as the benefits to the local community, could mitigate any opposition from the local community. Transparency about the development process as well as appropriate contingency plans outlining required actions and the allocation of responsibilities if something goes wrong can provide reassurance.

4.67 Following on from the IoD report, UKOOG commissioned Ernst & Young (2014) to further examine the prospects of a UK shale gas industry, including the growth of supply chains serving the sector. Its estimates are based on the development scenario used in the IoD report (2013), namely 4,000 wells drilled in the UK by 2032, requiring £33 bn of investment. The report estimates that at peak time a total of 64,500 jobs would be created from upstream activities, with 6,000 direct jobs, 40,000 indirect or supply chain jobs, and approximately 19,000 induced jobs. This implies an indirect and induced employment multiplier of 9.8 at a UK level, which is much higher than many of the comparable US studies.

4.68 The report also emphasizes that the UK oilfield service and manufacturing companies have an opportunity to develop their sector, as the development of shale gas requires specialist equipment and skills for hydraulic fracturing totalling £17 billion (out of the £33 billion). This includes pumps, trucks and blenders, which are currently supplied from outside the UK. A further £4.1 billions' worth of waste, storage and transportation equipment will be needed, as well as a £2.3 billion steel requirement. EY (2014) confirm that the UK has the ability to produce this volume and value of steel and equipment, but further research and investment will be needed to realise this potential.

4.69 Additionally, the study highlights an opportunity for the UK to develop a new £1.6 billion rig manufacturing industry, since the industry would need an estimated fifty landward rigs at peak drilling activity and a number of workover rigs. Moreover, the existing UK suppliers of cement, sand, drilling fluids and transportation can break into this market with the help from the shale gas industry and cooperation on ensuring standardised practices and common infrastructure plans.

4.70 The assessment of UK water management industry shows that UK suppliers have the facilities to perform water treatment procedures and drilling waste management (particularly in the North of England), although increased capacity would be required to treat waste volumes at peak. The need for waste storage and transportation infrastructure will depend on the proportion of treatment processes that can be conducted on-site, although there are no supply constraints anticipated. Furthermore, the UK has a well-developed waste transportation industry, with services for unconventional wells already established.

4.71 The report sets out two specific recommendations, firstly defining a set of standard skills, qualifications and/or accreditations required by operators for staff to work on shale projects, and secondly defining a plan and investment case to develop required skills at pace. Further recommendations include:

- Working with supply chain providers to gain a common understanding of requirements needed in R&D
- Defining common pad and hydraulic fracturing standards
- Expanding the Fabricator's Directory to include detailed specification of components required for onshore shale development, and work with the Government to promote UK-based suppliers with the capability to deliver to those specifications
- Working with the existing Government schemes (e.g. the Manufacturing Advisory Service) to raise awareness of the supply chain opportunities for existing businesses.

4.72 The Environment Agency also commissioned a report to aid its understanding of what a potential shale gas and coalbed methane development in England might look like on a commercial scale. This was a report by Ricardo-AEA (2014) *Unconventional Gas in England: Description of infrastructure and future costs*.

4.73 The report provides three development scenarios for both shale gas and coalbed methane along with associated costs. For shale gas, the study assumes that 12,478 wells would be drilled in total, with one lateral per well. This is equivalent to 3,095 wells under the mid scenario and 580 wells under the low scenario. Given the International Energy Agency's price projections for 2035, commercial extraction is said to be viable only in the mid and high scenarios. For coalbed methane, the scenarios assume 14,000 wells under the high scenario, 1080 under mid, and 230 wells under the low development scenario.

4.74 The report highlights a number of challenges the UK needs to overcome before achieving commercial development of unconventional gas. These include permitting, leasing and legal considerations, regulatory experience of onshore installations, achieving lower extraction costs, developing the infrastructure for drilling, fracturing and completions.

4.75 For coalbed methane it would take several years for production to be in full swing, in order to address regulatory and technical issues. Intensive development could then take place over a period of 3 to 10 years, followed by a period of more stable production.

4.76 The report by an Independent Expert Scientific Panel for the Scottish Government (2014) outlines the challenges for Scotland in developing an unconventional gas industry, which could also be applicable for Wales. It covers issues such as environmental impacts, impacts on gas prices and the petrochemical industry.

4.77 The report mentions issues such as truck movements, temporary visual impacts during drilling and other issues, which could arise due to proximity of long term plants to other properties. However, truck movements could be minimised where water supply can be obtained from the public water mains, or by licenced abstraction from a nearby waterbody.

4.78 The report also states that the interconnectedness of the gas market in Europe means that the benefits to the UK economy from unconventional gas production in the UK will be limited, since production would enter the European wide market, and therefore any impact on prices and supplies would be marginal. However, the report is hopeful that the development of the industry could provide suitable petrochemical feedstocks, reviving the UK petrochemical industry, especially since the availability of feedstocks from the North Sea is declining.

4.79 These conclusions mirror those of the House of Common Parliamentary Select Committee report[101] which concluded that "*it is too early to say whether domestic production of shale gas could result in cheaper gas prices in the UK. It is unlikely that the US experience will be directly replicated in the UK because of differences in geology, public attitudes, regulations and technological uncertainties. Shale oil is likely to be present in the UK but it remains uncertain whether industry will consider shale oil economically worthwhile to explore*". Likewise, the House of Lords Economic Affairs Committee report[102] concluded that "*Even if its economically recoverable reserves of shale gas prove substantial, the UK is not likely to see gas price cuts on the scale of those in the US*".

4.80 Table 4.2 provides a summary of the findings of the three main national impacts assessments undertaken for the UK to date.

[101] House of Commons (2013) The Impact of Shale Gas on Energy Markets, Seventh Report Energy and Climate Change Committee.

[102] House of Lords Economic Affairs Committee (2014) The Economic Impact on UK Energy Policy of Shale Gas and Oil, Third Report.

Table 4.2 Summary of Key Assumptions and Estimated Economic Impacts of UK Shale Gas Studies

	IoD	EY	DECC SEA	
Date Undertaken	2013	2014	2013	
Development Scenario	Central	Central	Low	High
Pads	100	100	30	120
Wells per pad	10	10	-	-
Laterals per well	4	4	6-12 (per pad)	12-24 (per pad)
Period of drilling	16 years (2016-2032)	16 years (2016-2032)	9 years	12 years
Production Lifetime	20 years	20 years	20 years	20 years
Scope of Coverage	Lifecycle	Upstream		
Total Development Expenditure (Lifetime)	£39bn	£33bn	£1.6bn- £3.2bn	£15.4bn - £26bn
Per Pad	£388m	£330m	£54 m- £107m	£107m-£215m
Per well	£38.8m	£33m	-	-
Per lateral	£9.7m	£8.25	£8.97m	£8.97m
Proportion of investment in UK	100%	100%	71%*	
Proportion of income spent in the UK	100%	100%	90%	
Laterals at peak (annually)	400	400	30-60	180-360
Employment per lateral (at peak):				
Total	185	161	89	89
Direct		15	71 (Direct& indirect)	71 (Direct& indirect)
Indirect		98		
Induced		48	18	18
Total Employment (at peak)				
Total	74,000	64,500	2,600-5,300	16,000-32,000
Direct		6,100		25,500 (Direct & indirect)
Indirect		39,400		
Induced		19,000		6,520

*Excluding spend on specialist workers and suppliers outside the UK

Regional and Local Impact Assessments

4.81 A number of assessments have been undertaken of the economic and employment impacts of unconventional gas in Lancashire and the Ocean Gateway area which includes parts of Cheshire, Merseyside and Greater Manchester. The Lancashire study was commissioned by Cuadrilla in 2011[103] in order to inform it's case-making to UK Government. This concluded that the development of an unconventional gas industry could provide important economic benefits for Lancashire and the UK.

4.82 The study suggested that for every £1 spent in the UK economy, the total effect is an increase in output in the UK economy of £1.70 on average concentrated in sectors most closely aligned with the goods and services, such as oil and gas extraction, iron and steel, special purpose machinery, construction and renting of machinery.

[103] Regeneris Consulting (2011) Economic Impact of Shale Gas Exploration & Production in Lancashire and the UK.

4.83 The study assessed the potential economic impact of industry development in two phases: first the drilling of three test wells and second the scaling up of activity to a commercial production phase in Lancashire.

4.84 The main conclusions for test phases were (see Table 4.33 below):

- 250 FTE jobs across the UK over a 12 months period during test well activity, considering there will be an average of three wells completed per year.
- Less than a fifth of these jobs would be supported in Lancashire (17% or 43), reflecting the extent to which supply chain expenditure leaks out to supplier in other parts of the UK and overseas.
- A half (125) of the estimated employment is associated with activities undertaken by Cuadrilla or first tier suppliers.
- It is estimated that around a third of total expenditure will go overseas: this leakage is due to the fact that the main drilling and fracturing equipment would be imported and would often require specialist overseas labour.

Table 4.3 Bowland Shale FTE Jobs generated by three test wells

	Lancashire	Rest of UK	All of UK
Direct and Indirect	21	176	197
Induced	22	31	53
Total	43	207	250
Implied jobs per well			**83**

Source: Regeneris Consulting (2011)

4.85 The shift to scaled-up commercial production within Lancashire extraction is based on a central scenario of 40 pads accommodating 10 wells each. At peak time, this is estimated to support around 5,460 FTE jobs at a UK level between 2016 and 2019. This would imply 4,000 direct and indirect jobs from main processes with a further 610 direct and indirect jobs required for installation of conversion infrastructure (ie infrastructure through which gas, or electricity from gas, flows into national networks). Induced jobs would account for 850 FTE nationally.

4.86 During the commercial extraction phase, the number of jobs taken by Lancashire residents is estimated to take up 30% of the total, representing 1,700 FTE jobs at peak.

Table 4.4 Employment Supported In the Bowland Shale Exploitation Central Case Scenario

	Direct & Indirect	Induced	Total	Per well equivalent
UK	4610	850	5460	95
Lancashire	1500	200	1700	30

Source: Regeneris Consulting (2011)

4.87 The economic and employment impacts of the future exploitation shale gas in the Ocean Gateway area of the North West of England was commissioned by IGas and Peel Developments in 2014[104]. The assessment uses a development scenario for the period 2015-2035 based on the development of 30 shale gas production sites, each site comprising 10 vertical production wells with 4 horizontal laterals (40 laterals per production site). The overall development activity

[104] AMION Consulting (2014) Potential Economic Impacts of Shale Gas in the Ocean Gateway.

therefore consists of a total of 300 vertical wells and 1,200 laterals, with overall investment totalling £9.8 billion. The intensity and duration of activity is similar therefore to the scenarios used in the IoD and Ernst and Young assessments.

4.88 Peak level employment is estimated to be around 15,500 FTE jobs in the UK, of which 3,500 (23%) are in the Ocean Gateway area. The UK employment is based on an assumption that all supply chain activity is located in the UK, which appears to be unrealistic given the poorly developed nature of the supply chain in the UK and the manner in which the sector will develop over time. The extent to which the development activity supports local employment is shaped in large part by the following assumptions:

- Given the duration of the exploration and production period, local residents have time to acquire the relevant skills, whilst others relocate permanently to the area. It is assumed that 40% of direct jobs are taken by people residing locally.
- The activity within the area of a sufficient scale for an assumed third (35%) of Tier 1 suppliers to locate their operations in the area, with subsequent tier operators co-locating some of their activity (up to 15%) in Ocean Gateway.

Table 4.5 Ocean Gateway Peak-Year FTE Employment Projections

	Direct	Indirect	Induced	Total	Per vertical well equivalent	Per lateral equivalent
Ocean Gateway	1,482	1,792	230	3,504	12	2.92
UK	2,914	6,444	6,184	15,542	52	13

Source: AMION Consulting (2014)

Other Evidence

4.89 Poyry (2013)[105] focuses on the potential for shale gas development in European countries. It estimates that in the case of shale gas development in the European Union, gas import dependency could go from 89% in the scenario of no shale development to 78% in the middle scenario of some development, and 62% in the case of significant industry growth. The report mentions, however, the reality could be very different to these estimations due to the strong linkages in the European gas market with US and Asia through liquefied natural gas (LNG), and potential development of shale gas in other parts of the world, including China, India, South Africa and Australia. These developments could put downward pressure on world gas prices, thus making imports cheaper and more attractive.

4.90 The report reaches fairly optimistic conclusions that shale gas development could result in lower gas and electricity wholesale prices. The projections in gas price reduction range from 6% to 14% depending on how rapidly the industry develops. Wholesale electricity prices could see a reduction between 3% and 8% according to their estimations.

4.91 The lower gas and electricity prices predicted in the shale gas development scenarios could also bring cost savings to industries within the EU, particularly the industries where gas and electricity make up a large proportion of costs. To some extent, these industries will pass lower costs onto consumers in the form of lower product prices, which would improve their competitive position in the markets, stimulating international demand for their goods.

[105] Poyry (2013) Macroeconomic effects of European shale gas production.

Summary of Impact Evidence

International Evidence

4.92 Unconventional oil and gas activity has been particularly prominent in the US, which has now become a prime evidence source for informing industry assessments around the world. As of 2012, there were over 7,700 unconventional gas well completions[106] in the lower 48 US states, producing 36 billion cubic feet (bcf) of unconventional gas per day. By 2035 this is estimated by IHS to rise to 80 bcf per day from 11,200 unconventional wells (although these estimates vary widely). As a result of such intensive unconventional gas industry development, the total activity has contributed an estimated $2.4 trillion[107] cumulatively to the US economy in gross value added (GVA) in 2012, predicted to almost double by 2035.

4.93 This surge in the development of the unconventional gas industry in the US has also had a major employment creation and supply chain impact. Again, whilst the estimates vary, analysts IHS provide one of the more authoritative estimates, which points to over 900,000 US jobs supported in 2012 by activity in the lower 48 States (split 190,000 direct, 280,000 indirect and 440,000 induced jobs). Unconventional oil activity contributed a further 845,000 jobs, of which 173,000 were direct, 260,000 indirect and 413,000 induced. The combined unconventional oil and gas activity is estimated to represent around 1.5% of total US employment.

4.94 One of the reasons for the extent to which employment has been created or supported in the US has been the strength of supply chains. For each direct job supported a further 1.5 jobs in the supply chain are supported (depending on how direct and indirect employment are classified). The unconventional oil and gas sector has been able to draw on the supply chain for the conventional oil and gas sector, as well as being strengthened in its own right by new investment being drawn into the sector and its supply chain. Substantial employment is supported in the oil and gas sector in its own right, as well as related manufacturing, scientific and environmental services, and a wide range of business and support services.

4.95 The US studies show mixed evidence of economic impacts at a State and County level where unconventional exploration and production occurs. The main conclusion is that local impacts can be diluted through more specialist employment being taken by mobile crews from outside the area, as well as the leakage of supply chain and personal expenditure. The key factors which influence this include:

- The phase of activity, with more scope in general for local residents to secure employment in the less specialist activities and longer durations of the post exploration, production period
- The scale of activity occurring, with the likelihood of greater impacts being built up as the level of activity ratchets up
- A presence of existing conventional oil and gas activity and the associated supply chains, influencing the extent to which suppliers and works have the experience and skills to secure opportunities in the unconventional sector
- At a more localised level, the extent to which local communities are able to accommodate and service the growth of the unconventional oil and gas activity.

[106] Well completion is the process of preparing a well, after drilling, for production (IHS, 2012).

[107] In 2012 prices

4.96 A theme in the US literature is the extent to which the expansion of the unconventional oil and gas industry can have a negative long term economic impact on local economies as a result of the boom and bust cycles. This has been a major issue in parts of the US in the past, as an energy fuelled expansion had diverted resources from other parts of the economy, making local economies less diversified. The current evidence is mixed on the extent to which this had arisen through the current shale oil and gas development in the US.

4.97 One of the significant negative effects in the US has been the damage to local roads infrastructure due to a large number of truck movements taking place during the construction phase of an unconventional gas well, requiring as many as 250 trips a day, combined with the fact that as much as a third of the roads in the US are unpaved. The different approach to regulation, plus the location of the developments and associated road infrastructure in the US, means that the potential for these impacts is both greater whilst also being less tightly controlled than would be the case in the UK.

4.98 Finally, the evidence points to the development of unconventional gas industry in the US having significantly reduced the price of natural gas, translating into lower local electricity prices as well as a reduction in the price of feedstocks for the basic chemicals and petrochemical industries. The latter has been particularly significant, with a number of commentators pointing to a revival in the US manufacturing industry through improved industry competitiveness.

UK Studies

4.99 Following the growth of unconventional gas exploration in the US and an increasing recognition of substantial resources in parts of the UK, a number of major studies have been undertaken on the potential economic impact of unconventional gas development in the UK. These include an SEA of the effects of future onshore oil and gas licensing by DECC, a report by the Institute of Directors (IoD), followed by a supply chain focused study by Ernst & Young, and a Ricardo-AEA report on infrastructure and development costs in England, all undertaken at a national level. Assessments have also examined the potential economic benefits associated with development in particular areas of the UK with considerable shale gas resources, typically commissioned by prospective operators.

4.100 This evidence is important as the experience in the US may not be mirrored in the UK, where the scale of the reserves, the economics of their extraction and the nature of the supply chains and skills base are very different. Given the limited development activity which has occurred to date in the UK, these assessments have tended to adopt a scenario based approach to allow for uncertainty for the growth and phasing of the potential industry. They are not typically based on detailed estimates of the economically and geologically recoverable reserves.

4.101 A number of the studies also make fairly optimistic assumptions about the intensity of activity and the potential for supply chains and skills to develop in the UK (or regions of it) enabling expenditure to be retained. In other instances, it is the higher scenarios which receive most attention in the reporting of the main findings. Nevertheless, the studies are important in pointing to the potential scale of economic and employment benefit, the constraints which could stifle development occurring in the first place or limit the economic benefits being realised nationally or locally, as well as the opportunities to secure benefits in a sensible way.

4.102 The sub-national studies that have been undertaken to date also point to significant local benefits in the area in which unconventional gas production might occur. The estimates point to between 1,700 and 3,500 FTE jobs in Lancashire and the Ocean Gateway area of the North West respectively, although the estimates are calculated on very different methods.

4.103 A range of studies have examined the potential competitiveness effects of shale gas activity in the UK, through the potential for lower energy and feedstock prices. The overall message is that whilst the evidence is fairly weak at the moment, the potential for a stimulus on a scale similar to that experienced in the US is limited.

5. Economic Impact Scenarios

5.1 Drawing on the previous chapters, this section of the report sets out the approach to estimating the potential economic impact of future unconventional oil and gas activity in Wales, based on the use of three development scenarios.

Development Scenarios

5.2 Given the uncertainty over the likely development path of the unconventional gas sector in the UK, we have used a range of scenarios to test the potential economic impacts of various development paths within Wales. The scenarios are specific to Wales, although given the close relationship between any development in Wales and the rest of the UK, they are designed to be broadly consistent with the development activity which may occur elsewhere in the UK.

5.3 Whilst there is too little information available on the technically recoverable resource in Wales to develop scenarios on the basis of the economics of extractable gas, the scenarios assess the core economic impacts associated with different levels of investment activity and hence exploration and production occurring within Wales. Whilst in practice the timing of the study does not enable us to take account of the award of 14th Round PEDLs, we have implicitly factored this potential into the scenarios.

5.4 In general, there is a more extensive economic impact evidence base for shale gas than for CBM or underground coal gasification. Whilst there are gaps in the evidence, there is sufficient information for us to differentiate between the extraction of shale gas and CBM (horizontally drilled) within the scenarios (although we do report the impacts of CBM and shale gas separately). This is not the case with underground coal gasification and for this reason it has not been identified separately.

5.5 The basis of the three scenarios is set out in Table 5.2 to 5.4 and in summary they are:

- **Low Scenario – Business as Usual**. Uncertainties and other barriers to widespread development remain. Global energy prices continue to provide limited incentives to invest in UCG in the UK. The likelihood of this scenario occurring is judged to be **moderate**.
- **Medium Scenario** – **Step Up in Exploration and Production in Wales**. A number of the barriers and aspects of uncertainty affecting the industry are lessened or removed. Global energy prices provide a greater incentive in developing extraction in the UK compared to the low scenario. The likelihood of this scenario occurring is judged to be **moderately high.**
- **High Scenario - Significant Step Change**. Uncertainty affecting the industry is greatly reduced stimulating significantly higher investment activity across the UK. Although not as rapid as in other parts of the UK, the increase in shale gas activity also occurs in Wales. This increase may also be stimulated by market factors such as a much higher increase in energy prices in the medium (eg 2-5 years) to long term (over 5 years). The likelihood of this scenario occurring is judged to be **fairly low.**

5.6 The proposed scenarios allow for a number of aspects of uncertainty, with more information on a number of these being provided in the next section:

- Overall time periods – we have modelled the economic impact of the activity which commences between 2015 and 2030, up to the decommissioning of this activity.

Consequently all of the expenditure associated with the lifecycle of the additional activity is captured and expenditure could feasibly occur up to 2045.

- Duration of production activity – the existing UK studies make varying assumptions for the duration of lifetime activity per well, and the proportion of this which accounted for actual production activity (ranging between 15 and 20 years productive life). Emerging experience from the US is pointing to shorter well lives and so we propose to err on the side of caution in assuming the following for a well: enabling activity in year one; site preparation in year two; drilling and testing in year three and possibly year four subject to the scale of activity; production over a 10-15 year period[108]; decommissioning over a one year period.
- Intensity of production activity – the evidence from the US suggests a high intensity of activity per pad for shale gas (i.e. number of laterals drilled per pad) and this has been reflected in a number of the UK studies with 40 laterals per pad being a common place assumption (10 vertical wells and four laterals per well). In line with the SEA for the 14th Licensing Round[109], there is not sufficient evidence to support this scale of activity and we propose to use a more conservative range to reflect the general uncertainty (between 10 and 24 vertical wells with laterals).
- Exploration and extraction lifetime costs – there is a great deal of uncertainty around the likely average costs of extraction for shale gas in the UK with an average of £9.3m per lateral well using estimates used in other UK studies. This cost estimate has been used as the basis of lifetime costs in our assessment with an allowance for economies of scale as production activity escalates at a UK and Wales level. There is far less information available for the extraction costs of CBM although the available evidence points to it being typically much lower. On the basis of the available information we have assumed lifetime capital expenditure (capex) and operational expenditure (opex) costs of £700,000 per well.
- Sourcing of inputs from within Wales - the UK does not currently have a well-developed supply chain for onshore oil and gas (eg there are currently very few mobile rigs in the UK and potentially limited capacity to manufacture these in the short term), although it is likely that the supply base (and the associated skills) will develop as the scale of exploration and extraction increases significantly. Our analysis of the supply side in the UK and Wales is set out in Section Six (as well as efforts nationally to promote the opportunities and encourage investment). This has informed the sourcing assumptions within the economic modelling, which are detailed at the end of that section, including the potential for the supply side within Wales to secure a higher share of activity as the scale of overall activity increases.
- Implications of technology choices in the supply chain – the nature of the technology and the choices which operators make can have important implications for the scale and location of economic impact. For example, some operators are currently investigating the potential to undertake the treatment of flow back on site with the reuse of chemicals. Whilst this would have significant resource efficiency benefits, it would both increase costs and the potential for local economic impacts. However, our analysis of the evidence

[108] The appropriateness of a 10 or 15 year timescale for production will need to be tested further, in light of more recent evidence from the US. Whilst it will have limited impact on the economic modelling, it may be important for the social and community impacts.

[109] DECC (2013) Strategic Environmental Assessment for Further Onshore Oil and Gas Licensing, Department of Energy and Climate Change

suggests that there is currently too much uncertainty about the likelihood of particular routes and their implications to merit modelling these in the economic impact assessment.

- Finally, it should be noted that these are economic scenarios which do not factor in assumptions about future policy decisions by UK or Welsh Governments.

5.7 Table 5.1 below provides an indication of the overall lifetime expenditure associated with each of the scenarios, allowing for a variation in the intensity of development on the pads under each of these scenarios.

Table 5.1 Estimate of gross capex and opex expenditure for differing scenarios (based on average per well exploration, drill and production costs), £million

	Low Intensity Drilling	High Intensity Drilling
Low Scenario - Business as Usual	£9.2	£13.1
Medium Scenario - Step up in Exploration and Production	£106.8	£235.0
High Scenario - Significant Step Change	£757.1	£1,780.4

Note: the difference in low and intensity drilling is driven by the assumption concerning the number of wells drilled per pad. That is, between 10 and 24 vertical wells with laterals per pad for shale gas and 4 to 6 wells per pad for CBM. See table 5.2-5.4 below for further details.

5.8 To put this into context with previous studies, the gross expenditure under the High Scenario with High Intensity Drilling represents c.4.5% of the total development cost under the commercial development scenario in the Institute of Directors (2013) report.

Table 5.2 Low Scenario - Business as Usual

	Fuel Type	**Exploration (bores drilled)**	**Pads**	**Well Intensity**		**Total Wells**		**Wells as a % of Other UK Studies' Production Assumptions**			
Basis of Scenario				Low	High	Low	High	DECC SEA		Institute of Directors	Ocean Gateway
								Low (360 wells)	High (2880)	Central (4000)	Central (1200)
Uncertainties and other barriers to widespread development remain. Energy prices continue to increase steadily. Consequently, on-going but limited exploration continues, leading to some small scale production later in the period. Exploration is initially focused on CBM and SG later in the period. Production activity is restricted to CBM in the period.	CBM	25.5	3	4	6	12	18	N/A	N/A	N/A	N/A
	Shale Gas			-	-			N/A	N/A	N/A	N/A
	Notes:	Assumes 17 existing licences and similar number through 14th licensing round. Average 0.75 bore holes per licence	Three CBM pads with production first coming on stream early 2020	Use of range allows for different potential intensity of drilling and well activity given the uncertainty about the resource. Approach broadly consistent with DECC SEA. Top of range of lower than IoD/E&Y/OG reports							

Table 5.3 Medium Low Scenario – Step up in Exploration and Production

Basis of Scenario	**Fuel Type**	**Exploration (bores drilled)**	**Pads**	**Well Intensity**		**Total Wells**		**Wells as a % of Other UK Studies' Production Assumptions**			
				Low	High	Low	High	DECC SEA		Institute of Directors	Ocean Gateway
								Low (360 wells)	High (2880)	Central (4000)	Central (1200)
A number of the barriers and aspects of uncertainty affecting the industry are lessened or removed and possibly a higher increase in energy prices than under the low scenario. A number of pads are developed in South East and North East Wales, with CBM development occurring sooner in the period, given the greater knowledge of the resource. SG production comes on stream later in the period (say 2025), given the greater time needed to establish the nature of the resource.	CBM	61	4	4	6	16	24	7%	2%		
	Shale Gas	41	1	10	24	10	24			0.6%	2.0%
	Notes:	Assumes 17 existing licences and similar number through 14th Rd. Average 3 bore holes per licence	Four CBM pads with production coming on stream 2020 onwards (split between NE and S Wales). A single SG pad comes on stream 2025.								

Table 5.4 High Scenario – Significant Step Change in Production and Large Scale Shale Gas Production

Basis of Scenario	Fuel Type	Exploration (bores drilled)	Pads	Well Intensity		Total Wells		Wells as a % of Other UK Studies' Production Assumptions			
				Low	High	Low	High	DECC SEA		Institute of Directors	Ocean Gateway
								Low (360 wells)	High (2880)	Central (4000)	Central (1200)
Uncertainty affecting the industry is greatly reduced stimulating significantly higher investment activity across the UK. Although not as rapid as in other parts of the UK, the increase in SG activity also occurs in Wales. This increase may also be stimulated by other supply side considerations, such as a much higher increase in energy prices. The assumed scale of development and production represents a higher share of UK high scenarios in order to test the potential supply chain impacts.	CBM	109	12	4	6	48	72	36%	9%		
	Shale Gas	231	8	10	24	80	192			4.8%	16.0%
	Notes:	Assumes 17 existing licences and similar number through 14th Rd. Average 10 bore holes per licence	Assumes 12 CBM pads and 8 SG pads. SG development and production occurs on a slightly delayed timescale compared to CBM (to be determined).								

6. Supply Chain Opportunities in Wales

6.1 This section examines the nature of the supply chain for the unconventional oil and gas sector and the manner in which this might develop within the UK and in particular within Wales. The analysis is used to inform the assumptions of the potential supply chain value which might be captured in Wales from the development of the sector and the manner in which this might vary depending upon the scale of development. In this way it informs the economic impact assessment which is presented in section 7.

The Supply Chain Opportunity

6.2 The uncertain prospects for the development of unconventional oil and gas in the UK has led to different commentators making a range of claims concerning the growth of the sector which could have serious implications both in terms of the need for the supply chain in the UK to expand to meet the needs of a rapidly growing sector, as well as the ability of operators to secure the inputs they require to support this growth.

6.3 As noted in section 4, there have been several estimates of the number of jobs that could be expected from the development of a UK shale industry ranging from 16,000 to as many as 74,000 direct, indirect and induced jobs during peak production in the mid-2020s. These estimates are however based on different scenarios envisaging different numbers of total of wells and well pads, different numbers of peak wells, different phasing of well completions and different methods to determine employment levels. Importantly not all make allowance for leakage and so the elements of the supply chain that are captured in the UK.

6.4 The purpose of this section is to outline the scope of supply chain opportunities, and those factors which may influence the penetration of employment and contract opportunities for Welsh businesses. The section points to three key factors:

- The scope of unconventional oil and gas development in the wider markets of the UK and Europe, as well as within Wales
- The speed with which the current industrial and service sector in Wales can re-align activity to match industry requirements
- The potential for inward investment by new firms to occur in Wales to meet any shortfall in the supply chain, or the extent to which it is met by providers located outside Wales (and indeed, suppliers in other parts of the UK, such as Scotland and the North East, will be seeking to supply the Welsh market).

6.5 The discussion suggests that the main areas for supply chain development in the UK could in time be specialised equipment, specialised steel casings, ancillary equipment, cement, logistics, and professional services. These opportunities might support a pattern of UK job creation not dissimilar to the US, though at a substantially lower scale. By means of example, the 2012 IHS report[110] outlines the nature of direct, industries and induced opportunities for producing and non-producing (see Table 6.1)

[110] HIS (2012) America's Energy Future: Volume 2 State Economic Contributions

Table 6.1 Selected Major Industries Benefiting from Unconventional Oil and Gas Activity in Producing States in the US

Direct	Indirect	Induced
Construction	Administrative & support services	Administrative & support services
Fabricated Metal Product Manufacturing	Construction	Amusement, Gambling and Recreational Industries
Machinery Manufacturing	Fabricated Metal Product Manufacturing	Educational Services
Mining (except Oil & Gas)	Financial and Insurance Services	Food and Beverage Stores
Oil & Gas Extraction	Management of Companies& Enterprises	Food Services and Drinking Places
Primary Metal Manufacturing	Monetary Authorities, Central Bank	General Merchandise Stores
Professional, Scientific and Technical Services	Professional, Scientific and Technical Services	Hospitals
Support Activities for Mining	Real Estate	Professional, Scientific and Technical Services
Truck Transportation	Truck Transportation	Real Estate
Utilities	Wholesalers	Wholesalers

Source: America's Energy Future: Volume 2 State Economic Contributions, IHS, 2012

Table 6.2 Selected Major Industries Benefiting from Unconventional Oil and Gas Activity in Non-Producing States in the US

Direct	Indirect	Induced
Chemical Manufacturing	Administrative & support services	Accommodation
Computer & Electronic Product Manufacturing	Construction	Administrative & support services
Fabricated Metal Product Manufacturing	Fabricated Metal Product Manufacturing	Educational Services
Machinery Manufacturing	Financial and Insurance Services	Food Services and Drinking Places
Mining (except Oil & Gas)	Machinery Manufacturing	General Merchandise Stores
Non-metallic Mineral Product Manufacturing	Primary Metal Manufacturing	Nursing and Residential Care Facilities
	Professional, Scientific and Technical Services	Professional, Scientific and Technical Services
	Real Estate	Real Estate
	Wholesalers	Wholesalers

Source: America's Energy Future: Volume 2 State Economic Contributions, IHS, 2012

Scope of the Opportunity

6.6 A number of recent UK studies have produced a detailed analysis of the supply chain opportunities for shale gas extraction in the UK[111]. The job estimates and sector development opportunities are based on a bottom-up appraisal that distinguishes, in this instance, between five phases of development and operation.

6.7 Although relating specifically to fracking, this framework can also be applied to Coal Bed Methane and Gasification. It provides an appropriate tool to analyse supply chain potential throughout the Welsh economy.

[111] The Ernst and Young report for UKOOG noted above and the OTM report for Innovate UK.

Phase 1: Non-intrusive Exploration and Permitting / Phase 2: Exploration

6.8 For the purposes of convenience, it is possible to group the first two phases together. This is because the nature of the technologies and the businesses involved share some important characteristics. For fracking, the emphasis is on what OTM (authors of a report on the shale gas supply chain for Innovate UK) has called Reservoir Analysis and Characterisation. This involves using existing data or new material to predict and forecast the prospects for field development and individual sites. The subsequent permitting activity sees the acquisition of planning and regulatory consents, involving geological and environmental assessments. The OTM report has defined the UK's position here as 'moderate' business potential, with major strengths being restricted to a small number of research institutions and universities. No Welsh institutions were noted as being particularly strong in this specialism.

6.9 For the exploration phase, fracking requires well pad and ancillary construction, drill rig hire, drill crew hire, mud engineering, further geological testing, the provision of fracking and frack fluid chemicals and other related activities. However unlike in the operational phase, the scale of this activity is likely to be limited. For example in Cuadrilla's application for exploration in Lancashire, the operation will see just four exploration wells operating from a single pad. It is also unclear whether it will be economically viable for exploration firms to develop indigenous supply and contracting relationships, or simply import resources from existing lower cost (US) service providers. Consultations suggest that this decision is finely balanced, through tending to favour existing service companies.

6.10 For Coal Bed Methane, exploration is aided by the significant volume of information available on the location of coal seams in the UK and the South Wales coalfields and their gas contents. Several companies are now at the pilot production stage, for example Tower Colliery in South Wales, but large-scale production in the UK is unlikely before 2016. Supply side opportunities in these early exploration phases have proved to be quite limited, with the major impact unlikely to be felt before full-scale operation commences.

6.11 Gasification uses directional drilling techniques that are commonplace in the oil and gas sector to follow the coal seam. Instead of digging the coal out, oxygen and water pumped down a shaft into coal beds creating a reaction that turns the coal into what is known as syngas. Activities benefit from a quite detailed picture of UK coal reserves, which has identified potential development areas in Cardiff Bay and North Wales. Supply chain opportunities here are likely to centre on exiting oil and gas service providers, who are best placed to adapt existing techniques and materials to what is still a relatively untested proposition.

Phase 3: Production Development

6.12 This phase will continue the drilling and fracking activity, but move from a single or small number of wells to multiple wells per pad where the gas reserve is quantified and justifies larger scale activity (so from 4 wells to 24 as assumed in the upper range of our scenarios in Section 6 or 40 wells assumed in the IoD and Ernst and Young Studies).

6.13 This area has greatest supply chain potential across all three technologies. Ernst and Young, have estimated that to bring a single fracking pad of 40 wells, consisting of 10 vertical wells each with four laterals) into operation would require total expenditure of at least £333m (when the sector is operating at a commercial scale). Major components of this demand are specialised equipment, quarrying, specialised steel casings, ancillary equipment, cement, logistics, and professional services.

6.14 Specialised fracturing, drill and related specialist equipment will be needed across all three areas. For fracking high pressure pumps, trucks and blenders are currently sourced from Europe. This offers an opportunity for those engaged in offshore support and other aspects of high value engineering to enter the UK supply chain. Several consultees have told us that this opportunity may be enhanced because UK safety regulations may require standard US and European equipment to be modified. Opportunities here are less dependent on co-location with drilling facilities, and more likely to occur on a national basis.

6.15 The drilling of the shale gas wells will also create a significant demand for steel casings. There are already at least two UK firms already supplying the offshore market, and these would be best placed to service industry requirements. However, the potential for UK steel producers to meet the needs of this new business could be lower when one considers the current global over-supply of specialised steel.

6.16 The amount of general activity retained in the UK will depend on the scale of production, and the characteristics of individual materials. Low value bulk material (cement) is likely to be sourced locally, as are basic chemicals and ancillary support activities (logistics, security, environmental services). Higher value, more specialised equipment will probably come from existing oilfield service companies or from the US. The balance between these sources will be determined by the speed which UK suppliers can align themselves to new industry requirements.

Phase 4: On-going Production

6.17 At this stage supply chain requirements drop off towards a steady state which could last as long a decade or more, depending on individual geologies. This is the most significant period in terms of site profitability, whilst the demands on the local labour force and business support infrastructure are at their lowest. Opportunities will arise around the provision of a pipeline infrastructure (gathering lines and integration into the gas network) or storage and transportation provision.

6.18 In addition, fracking activities of all types will also require large amounts of water and handling solutions need to be locally focused so as reduce environmental impact. Produced or formation water could also be generated which will require treatment, although this is most likely with CBM. There are also opportunities for both the technology underpinning waste water handling and the treatment activity itself. The area was identified as a significant area of opportunity by both Ernst and Young and OTM.

6.19 There may also be a requirement for additional refracturing during stage 4, supporting further supply chain opportunities in addition to those noted under phase 2 and 3.

Phase 5: Decommissioning

6.20 Here the precise requirements of the sector are less well articulated. Environmental waste management and professional surveying services will all be required to ensure sites are returned to a fit and stable condition. Decommissioning activity is unlikely to begin for a decade or more, allowing UK based organisations to design a tailored service to unconventional gas operators.

6.21 For all stages, logistics support and the supply of professional and legal services will be important to the success of developing unconventional oil gas. However, it is likely that those spatial areas (e.g. Scotland) more closely associated with the offshore oil and gas industry will be best placed to benefit the most.

6.22 It is clear that the potential for an unconventional oil and gas supply chain to develop in Wales is related to, but not limited by the development of indigenous fracking, CBM and gasification activity. The supply chain links are likely to be stronger in the development, operational and decommissioning areas, where local engineering, water treatment and logistics companies could benefit from wider developments in the UK and Europe. However, to do so they must prove responsive to operators requirements. They will also have to challenge existing oilfield service companies and new inward investors in other parts of the UK. In doing so, skills and investment capital will be vital enabling forces. These are considered in more detail below.

Supply Chain Opportunities in Wales

Current Opportunities – the Low and Medium Scenarios

6.23 One of the challenges of the economic impact assessment for Wales is the determination of reasonable assumptions on the amounts of local sourcing that might be connected to future unconventional gas development. Moreover, we have to be aware that the current structure of the supply side of the economy in Wales could change were the industry to grow such that new firms could come in to serve this industry, or new indigenous firms could set up. There are therefore a series of unknown factors.

6.24 However, we expect that the evolution of the unconventional gas sector in other parts of the UK and Europe will have a marked effect on the extent to which future development in Wales will be able to take advantage of a local supply side. For example, if developers access commercially significant shale gas deposits in other parts of the UK prior to Wales, as seems likely, then suppliers in other regions may gain a strong element of first mover advantage. A corollary here is the challenge for existing Welsh firms with appropriate expertise to win opportunities in expected shale gas development projects in other parts of the UK, therefore putting them in a better position to win business once, and if, development occurs in Wales.

6.25 We have used our review of previous studies of unconventional gas development in the USA and Europe to explore the different types of commodities employed in both developing and operating shale gas and coal bed methane, and how developers typically distributed expenditure. In particular a large number of studies of the economic impact of unconventional gas have taken place in the USA and have used economic modelling frameworks similar to those employed in this report (see Appendix A).

6.26 These types of studies were an important source of reference material; in particular in terms of how such studies related unconventional gas development and operational expenditure to industries described in US Input-Output modelling frameworks (such as the IMPLAN System). Then we have examined the typical distribution of development and operational spending found in a series of US studies and then linked these to UK industrial sectors (Standard Industrial Classification, SIC 2007).

6.27 Table 6.3 below shows an estimate of how we expect typical development and operational spending on unconventional gas development (combining both shale and coal bed methane) to be spread across UK defined industries. Note here that this includes industry activity in terms of drilling capital spending, completions, facilities and gathering capital spending, as well as on-going operational expenditure (covering phases 1-4 discussed earlier in this section).

6.28 The analysis reveals that around one quarter of total spending relates to the defined “Support activities for petroleum and natural gas extraction” and with around 18% estimated to be spent in the “Manufacture of metal structures and parts of structures”. Around 8% would be spending on the products of the “Operation of gravel and sand pits etc.” sector. Immediately apparent here is that even at this level of disaggregation (five digit Standard Industrial Classification 2007) there could be fairly diverse activities within the industry classification. For example, while around 4% of spending is on “Manufacture of fluid power equipment and pumps” this embraces many different types of equipment some of which would not be suitable for use in the unconventional gas industry.

6.29 This becomes a very real issue when we move to local sourcing assumptions for Wales. Whilst Wales may have strong representation in a sector such as “Manufacture of metal structures etc.”, it is not clear whether this industry in Wales would be able to produce the specific requirements of the unconventional gas industry or indeed whether it would be willing to serve a small evolving sector.

6.30 These caveats noted, the third, fourth and fifth columns of Table 6.3 provide an outline of how far the sectors which could serve the unconventional gas sector are actually present in Wales. This becomes one means of providing broad local sourcing assumptions for the economic impact analysis:

6.31 Column three provides estimates of employment in these sectors in Wales (from the ONS Business Register and Employment Survey) revealing that there were (in 2013) over 21,000 people in Wales employed in sectors that could link to and serve the supply chain of unconventional gas.

6.32 Column four shows a simple location quotient for these five digit industries. A location quotient (LQ) measures a region's industrial specialisation relative to a larger geographic unit (the UK here). Here the LQ is computed as an industry's share of a regional total employment divided by the industry's share of the national total of employment. For example, the LQ of 1.41 in "Operation of gravel and sandpits means that Wales has a 41% higher concentration in this sector than the UK on average. Were this LQ to have a value 1.0 then Wales would have a share similar to the UK average.

6.33 The location quotient (LQ) analysis reveals that Wales has relatively high shares of employment in sectors such as Operation of gravel pits, Manufacture of cement, Manufacture of metal structures, Manufacture of tubes and fittings of steel, Manufacture of electronic components, Manufacture of tanks and containers of metal, and Manufacture of steam generators.

6.34 The current weaknesses in the supply chain in Wales when compared to the likely supply chain profile for unconventional gas development are fairly apparent. For example it was estimated that "Support activities for petroleum and natural gas" could account for around one quarter of total developmental and operational expenditure, while the LQ analysis reveals relatively little activity in Wales. On this basis there is better evidence for supply chain links in sectors such as Operation of gravel pits and Manufacture of metal structures, where these sectors account for a larger part of total development and operational spending and where there is relatively strong representation in the Welsh economy.

6.35 A further check on the presence of these potential supply chain sectors in Wales is through an analysis of the number of registered offices where local firms list the five digit Standard Industrial Classification as their main activity (column five). This was derived from the Jordan FAME database. Clearly, this takes no account of the size of operation represented by the registered office but hints at the depth of the regional supply side in these industries. This reveals larger numbers of registered offices in sectors such as Support activities for petroleum and natural gas (25), Manufacture of metal structures (184), Manufacture of inorganic chemicals (35), Freight transport (627), Electronic components (40) and Professional services (245).

6.36 Column six of the table presents the estimates of local sourcing assumptions that would link with the low (Business as Usual) and medium (Step-up) scenarios (see section 5). Generally the expectation is of higher levels of Welsh sourcing of goods and services where there is a higher local presence in the industry, and with selected sectors producing commodities that are expensive to transport such as cement and mined/quarried products. We expect far lower levels of local sourcing in some specific manufacturing sectors and in the "Support services for petroleum and natural gas extraction" where there is relatively little employment presence currently.

Table 6.3 Wales Sourcing Assumptions by Sector for the Low, Medium and High Development Scenarios

Description of Activity	Share Total UCG Spending (%)	Employ -ment in Wales (2013)	Location Quotient Wales	No. Registered Offices	Local sourcing Scenario: Low/Med	Local Sourcing Scenario: High
Support activities for petroleum and natural gas extraction	24.6	<200	0.12	25	5%	15%
Operation of gravel and sand pits; mining of clays etc	8.2	440	1.41	7	75%	75%
Manufacture of cement	0.3	240	2.65	3	75%	75%
Manufacture of metal structures and parts of structures	18.3	3,580	1.62	184	75%	75%
Manufacture of tools	7.2	370	0.56	15	15%	15%
Manufacture of machinery for mining	9.9	<100	0.12	4	0%	0%
Manufacture of fluid power equipment/pumps	4.3	380	0.47	6	0%	15%
Manufacture of compressors	6.2	<100	0.03	0	0%	0%
Manufacture of tubes, pipes and fittings of steel	2.1	380	1.10	9	15%	30%
Sewerage inc treatment of waste water	4.1	906	0.85	35	100%	100%
Manufacture of other inorganic basic chemicals	4.1	<200	0.94	17	15%	15%
Manufacture of industrial gas	4.1	90	0.79	0	50%	80%
Freight transport by road	0.6	8,100	0.97	627	80%	80%
Manufacture of other tanks and containers of metal	1.5	290	1.38	6	15%	30%
Manufacture of electronic components	0.6	1,840	2.47	40	50%	50%
Manufacture of electrical instruments	0.2	1,060	0.51	21	15%	30%
Manufacture of engines and turbines	0.1	770	1.04	4	0%	0%
Manufacture of steam generators	0.1	150	1.64	0	0%	0%
Professional services including engineering related scientific and technical services (see Note)	3.4	2,840	0.89	245	50%	75%
	100.0	21,440		1248.0		

Note: Planning, design and legal services associated with project development were modelled in the analysis that follows as part of professional services as this links to the sector descriptor in the Welsh Input-Output tables.

6.37 In the medium scenario, we apply the same local sourcing assumptions as for the low scenario but adjust the spending to include local community benefit payments in a range £1.86m to £4.33m (i.e. around 2% of total expenditure) due to the inclusion of shale gas in the production mix (and indeed this process with respect to community benefits is replicated for the high scenario, but with a higher expenditure level to reflect the higher scale of activity).

Future Opportunities – the High Scenario

6.38 Our high scenario (Significant Step Change) sees a major uplift in shale gas production activity and a range of total expenditure on lateral well drill and production of £772.0m (High Scenario – Lower Intensity) to £1,815.0m (High Scenario – Higher Intensity). Note in both cases here this includes an element in terms of spending on community benefits. We expect this level of activity to lead to:

- Some new inward investment into Wales to supply the sector and with it the development in the indigenous supply side as a result
- Firms in relevant Welsh sectors diversifying and expanding to meet the demand, particularly in cases where there is already regional employment representation and where there is greater scope for diversification to meet growing demand.

6.39 The final column of Table 6.3 shows the higher local sourcing proportions that are used to inform the economic modelling of the High Scenario. In particular we expect local sourcing to grow in "Support activities for petroleum and natural gas extraction" from 5% to around 15%. With an increase in activity businesses in this sector tend to be fairly mobile and able to respond to new opportunities in different places. We also expect some expansion of local sourcing with higher levels of industry activity in Professional services for much the same reason, although here this would be from an existing base of activity and could reflect diversification of existing firms in the sector in Wales to serve the unconventional gas sector.

6.40 The local sourcing assumptions have also been adjusted upwards for selected manufacturing where we believe there is scope for expansion from a relatively low base of activity including manufacture of fluid power equipment and pumps, manufacture of tubes and pipes, manufacture of tanks, and manufacture of electrical instruments. While we accept these local sourcing scenarios reflect an element of judgement in terms of the proportions that could be purchases from local firms we have attempted to be conservative in developing the local service scenarios under the Low, Medium and High activity scenarios.

Expenditure Assumptions

6.41 Table 6.4 shows the total expenditure connected to the different scenario and intensity mixes, but then with the amounts of regional spending that are connected to the different scenario and intensity mixes. Here we apply the assumptions for the distribution of total spending from Table 6.4 to the local sourcing scenarios in the final two columns of Table 6.3[112].

[112] Note that the total spending distribution in Table 6.4 for the Medium and High Scenarios excludes the community benefits which are included in the overall economic analysis but assessed separately.

Table 6.4 Sector Spending In Wales by Scenario and Intensity of Activity £000s

Scenario	Scenarios					
	Low Scenario		Medium Scenario		High Scenario	
	Lower Intensity	Higher Intensity	Lower Intensity	Higher Intensity	Lower Intensity	Higher Intensity
Total CAPEX and OPEX	**9,210.0**	**13,050.0**	**106,811.4**	**235,000.1**	**757,141.5**	**1,780,352.4**
of which regional spending by sector:						
Support activities for petroleum and natural gas extraction	113.2	160.4	1,312.7	2,888.1	27,915.7	65,641.4
Operation of gravel and sand pits; mining of clays	564.2	799.5	6,543.4	14,396.3	46,383.2	109,066.1
Manufacture of cement	21.4	30.3	247.6	544.8	1,755.2	4,127.2
Manufacture of metal structures and parts of structures	1,265.3	1,792.9	14,674.5	32,286.0	104,021.5	244,597.6
Manufacture of tools	99.6	141.2	1,155.5	2,542.3	8,190.9	19,260.3
Manufacture of machinery for mining	-	-	-	-	-	-
Manufacture of fluid power equipment/pumps	-	-	-	-	4,907.5	11,539.4
Manufacture of compressors	-	-	-	-	-	-
Manufacture of tubes, pipes and fittings of steel	29.5	41.8	342.3	753.0	4,852.2	11,409.4
Sewerage inc treatment of waste water	376.1	533.0	4,362.2	9,597.6	30,922.1	72,710.7
Manufacture of other inorganic basic chemicals	56.4	79.9	654.3	1,439.6	4,638.3	10,906.6
Manufacture of industrial gas	188.1	266.5	2,181.1	4,798.8	24,737.7	58,168.6
Freight transport by road	41.7	59.1	483.4	1,063.4	3,426.3	8,056.6
Manufacture of tanks and metal containers	20.5	29.1	237.9	523.4	3,372.7	7,930.7
Manufacture of electronic components	29.3	41.5	339.9	747.7	2,409.1	5,664.8
Manufacture of electrical instruments	2.9	4.2	34.0	74.8	481.8	1,133.0
Manufacture of engines and turbines	-	-	-	-	-	-
Manufacture of steam generators	-	-	-	-	-	-
Professional services	156.3	221.5	1,812.6	3,987.9	19,272.8	45,318.3
Total Local Spend	**2,964.6**	**4,200.6**	**34,381.3**	**75,643.7**	**287,287.1**	**675,530.7**
Spend in Wales as % of All Spend	**32%**	**32%**	**32%**	**32%**	**38%**	**38%**

Note: Total spend in wales excludes community payments and land purchase or access payments

Summary

6.42 The section has considered the evidence presented in a number of UK studies of the scope for a supply chain to develop in the UK as the extent of unconventional gas expands. These studies suggest that key influences on the scope to secure supply chain benefits (and the associated economic and employment benefits) are the extent and pace at which unconventional oil and gas development occurs in the UK (and to some extent wider markets in the Europe) and the pace at which current industrial and service sector can respond to and re-align activity to match industry requirements.

6.43 The evidence suggests that the main areas for supply chain development in the UK could in time be specialised equipment, specialised steel casings, ancillary equipment, cement, logistics, and professional services. These opportunities might support a pattern of UK job creation not dissimilar to the US, though at a substantially lower scale.

6.44 One of the challenges of the economic impact assessment for Wales is the determination of reasonable assumptions on the amounts of local sourcing that might be connected to future unconventional gas development. Moreover, there is the potential for the current structure of the supply side of the economy in Wales to change were the unconventional gas sector to grow rapidly as indigenous firms respond, firms are set-up or inward investors move in response to the opportunity.

6.45 However, current available evidence points to growth of the unconventional gas sector in other parts of the UK and Europe at a pace and scale ahead of Wales, which will have a marked effect on the extent to which the supplier base in Wales can take advantage of future development.

6.46 Using an analysis of the industrial mix in Wales and the pattern of expenditure across the unconventional gas lifecycle, we conclude that under the low and medium scenario around 32% of expenditure will be retained in Wales. If development were to occur at the higher rate assumed in the high development scenarios, expenditure retention would rise to around 38%.

6.47 In terms of the targeting of sectors in Wales (either through marketing the area to new inward investment, or encouraging existing firms) the areas in which there could be scope to promote opportunities in Wales include:

- Steel products sectors and the manufacture of structures required to support fracturing operations (here the emphasis might be on encouraging an existing stock of firms)
- Mineral products production to support fracturing, as well as the production of cement (working through organisations such as Mineral Products Association to make sure the players in Wales are awake to possible opportunities)
- Associated civil engineering activity to get operations up and running
- Whilst waste and treatment facilities and providers are present in Wales, there could be steps which could be taken to ensure they are prepared for the opportunities which unconventional gas could bring (there should be extensive experience in Wales already in terms of innovative ways in dealing with mining and quarrying discharges).

6.48 There is academic expertise throughout the Universities in Wales, including research, development and commercialisation covering physical, geological and landscape, and environmental effects of different fracturing techniques. However, the extent to which Wales has advantages over other universities in the UK in these areas is unclear, with competition to win research funding in these areas being very intense.

7. Estimated Economic Impact in Wales

Economic Assessment Approach

7.1 This section describes the methodology used to generate our estimates of the potential regional economic impact of unconventional gas exploitation in Wales. It is important to recognise here that the focus is on economic activity supported in the Welsh economy. Any expansion of hydrocarbon production in Wales would be expected to have a series of UK wide effects as well, although these are outside the scope of this particular study. The economic impacts of Welsh suppliers accessing opportunities in other parts of the UK has been examined, but in a more qualitative manner than the approach described here for Welsh regional economy impacts.

7.2 The assessment estimates the potential value of investment in terms of the gross value added and employment (full time equivalent jobs) supported within the Welsh economy. Whilst the method and outputs largely mirrors work undertaken for other energy sectors in Wales (for example recent research undertaken by Regeneris and Cardiff University for on onshore wind and marine renewables), there are a number of important differences and restrictions to the current analysis.

7.3 Firstly, previous energy studies focused on the construction of facilities, or development of sectors in the field of electricity generation. Clearly the current study examines mineral extraction activities, albeit for a fuel that could be used in part for electricity generation or domestic use. Whilst this distinction is mostly irrelevant in the assessment of regional economic impact, it does mean that a number of metrics reported in previous energy studies – chiefly employment per MW of installed capacity – are not applicable and hence not reported.

7.4 Secondly, there are more challenging issues around the quality and comparability of data and the manner in which it can be used to inform the development of the scenarios for this assessment. Whilst there is a good evidence base in the US, there are also very different regulatory and institutional conditions, as well as a very different geology and economic geography. The available evidence suggests that these could be important differences in terms of the potential scale and nature of the development of the unconventional gas sector in the UK.

7.5 Data on commercial extraction of shale gas and coalbed methane in Europe are scarce, for the reason that very little production has hitherto occurred. Even in countries where there is a proven resource, and a reasonably positive government approach (e.g. Poland, Bulgaria), progress has been slow and characterised by an unwillingness of international capital to invest[113]. Europe is in a 'chicken-and-egg' situation, where hundreds to thousands of test wells are required to fully appraise the recoverable resource, but where regulatory constraints, public-opinion and other barriers combine with the low price of gas (in part due to US shale supplies) to discourage such investment[114]. The paucity of real data on commercial unconventional gas extraction, per well and in aggregate total, means that the costs, scenarios and economic impact described in this report must be treated with caution.

Outline Methodology

7.6 The assessment uses the Input-Output (IO) Tables for Wales in order to estimate the gross value added (GVA) and full-time equivalent employment that might be supported in Wales under each of the three production scenarios. The IO Tables allow an assessment of the direct (on-site), indirect (supply chain) and induced (wage related) effects of new or potential economic activity (albeit here, as already noted, with significant caveats regarding data quality and scenario reliability). Input-

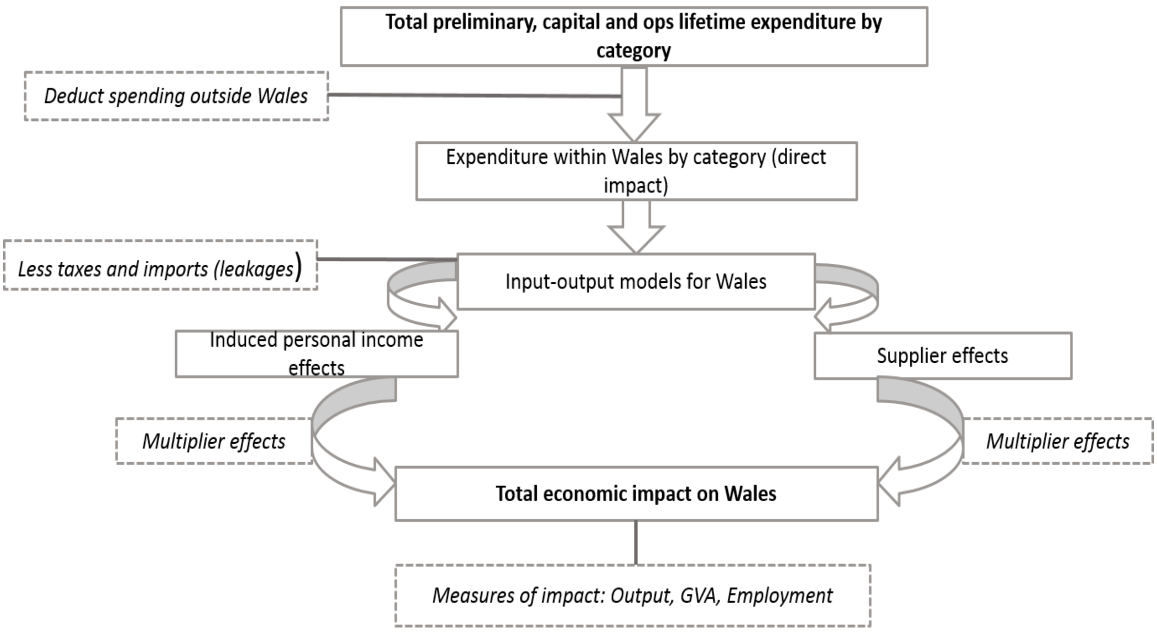
[113] http://www.brookings.edu/research/opinions/2013/11/15-shale-gas-oil-boom-europe-boersma

[114] http://www.lngworldnews.com/wood-mackenzie-cautions-commercial-viability-of-uk-shale-gas-remains-to-be-proven/

Output frameworks of this type have been commonly used in the US to assess the state-wide impacts of shale gas investments.

7.7 Figure 7.1 illustrates the conceptual model used in the assessment; new economic activity at shale extraction locations generates new economic activity in Wales, directly on site, and then as shale (or coal bed methane) extractors demand Welsh labour, goods and services in pursuit of gas extraction, with these supply chain impacts potentially extending for some rounds along the supply chain. Further economic activity is also induced as workers in shale and supplying companies spend their wages, in part, in Wales.

Figure 7.1 Broad Structure for the Modelling Approach



Source: WERU, Cardiff University

7.8 In parallel with other studies of shale gas related economic impacts explored in Section 4 there is an issue with the identification and distinction made between direct and indirect impacts (labour and GVA). We would expect, for unconventional gas, the scale of *on-site* subcontracting to be both extensive but uncertain. The extent of such activity fundamentally drives the scale of the economic multiplier (which is the impact total divided by direct impact), albeit with no impact on the overall level of activity generated in Wales. In common with earlier assessments undertaken on the energy sector in Wales[115] we therefore do not report direct and indirect impacts separately in this study (or any economic multipliers).

7.9 Whilst Input-Output analysis has a longstanding track record in Wales, using regionally bespoke tools and data, it faces a number of inherent limitations and simplifications. For example, it is very difficult to account for economies of scale, the changes in technological approach or the geographies and adjustment of supply chains (although our scenario analysis is intended to address this latter concern)[116].

7.10 For the as-yet regionally untested unconventional gas activities the methodological constraints are more challenging yet. For example, the likely industrial geography and evolution of shale extraction

[115] 2013: Welsh Government. Marine renewables economic impact analysis, Regeneris Consulting and Cardiff University. 2012-2013: Welsh Government. Energy Sector Employment Multipliers study, Cardiff University and Regeneris Consulting.

[116] For far greater detail see Miller R, and Blair P (2009) *Input-Output: Foundations and Extensions 2nd ed.* (Cambridge University Press, Cambridge)

in the UK (or Europe) is unknown. In the US, the industry is characterised by a far higher level of peripatetic capital than is the norm for other industries, driven by the short drilling and set-up periods and relatively short extractive life of shale (gas and oil) wells. In the US, there has been a need to constantly drill in new locations to maintain production, although this could in part be due to the economics of the sector in the US.

7.11 Indeed in the input-output frameworks used by researchers in the US there is commonly a specific oil and gas drilling services sector within the tables which is absent in the Wales framework. Our view of the 'embeddedness' of capital in Wales will drive modelling assumptions and hence levels of reported economic impact. Additionally, US tight production is characterised by the convergence at well-heads of multiple companies with experience in onshore oil and gas combining knowledge and machinery to undertake extraction and distribution operations. Given the limited onshore oil and gas expertise, infrastructure and relevant tooling in Europe, the mode of operation (and hence the modelled production function) here is uncertain.

7.12 The above issues notwithstanding, IO analysis is the most appropriate and regionally oriented methodology available to assess the positive economic impacts of potential unconventional gas extraction in Wales. Given the nature of available data on experience elsewhere and the uncertainties around the recoverable resources in Wales, we use a well as our core unit of analysis rather than the volume of gas extracted. The assessment therefore seeks to establish the economic impact per well, with this then grossed up to the (assumed) overall number of wells and pads in our relative scenarios.

7.13 It should be noted that this aspect of the assessment deals only with the positive economic impact associated with unconventional gas extraction. It makes no comment on the likelihood or *viability* of such investments given wider economic, energy cost, environmental and social contexts. These issues are addressed in other sections of the report.

Data Sources

7.14 A range of data sources are required to inform the assessment, including estimates of capital and operational spending associated with commercial shale gas and CBM extraction in Wales. To ensure consistency with other studies this required estimates of the expenditure associated with the different phases of activity. This, unlike for some much longer-lived investments[117], also included decommissioning costs (which will inflate economic impact estimates for unconventional gas compared to other developments). Relevant expenditures were then categorised according to the 88 sectors in the Welsh Input-Output Tables, with an assumption made in each case around how much of that expenditure is likely to occur in Wales as opposed elsewhere (either under current or improved local supply conditions).

7.15 As noted earlier, the data available to estimate the likely pattern of expenditures in UK commercial shale and CBM exploitation are very limited (and all of course *ex ante* estimates) – and there is no robust data on the level of regional sourcing. A number of studies exist and have been drawn upon in developing our proposed approach (see Section 2) but it should be noted that few of these studies meet the highest standards in terms of their robustness, transparency or impartiality. Methodology and data sources are in some regards vague, coverage and classifications vary, and in some cases sponsoring bodies have an interest in, or declared preference for, shale and CBM development in the UK.

7.16 There are a small number of US studies based on actual commercial exploitation, in the Magellan shales and in the lower-48 states overall (for shale gas and tight oil). As shown above, these studies use a similar IO approach to our own study and hence, usefully, present estimates of spending according to specific and detailed industrial classification; and for exploration, drilling and operations

[117] Such as the 100+year Swansea Bay Tidal Lagoon; WERU (2013) Turning Tide: the economic significance of the Tidal Lagoon, Swansea Bay http://tidallagoon.opendebate.co.uk/files/TidalLagoon/DCO_Application/6.4_22.1.PDF

separately. There is a significant caveat here however, in that it is not known how the production of shale and CBM will occur economically in Europe, but it is unlikely to be identical to the USA – due to geological, infrastructure and other factors. However, in the absence of Europe-specific data, US evidence on the different vectors of spend associated with exploitation has been useful, even if overall cost per MMTU in the UK will probably be significantly higher.

7.17 The analysis amalgamates US data on spend vectors with UK estimates on costs (with some of this by broad activity) to produce an estimate of the cost per well for UK shale gas and coal bed methane, with this disaggregated by 88 industrial sectors. Given uncertainty over the evolution of shale exploitation, the assessment has used total costs for the lifetime of the well, presented in 2014 prices.

7.18 The assessment has then used the authors extensive knowledge of relevant supply side activities in Wales to estimate the level of local sourcing associated with each input, and in the supply of labour (with these varying in the scenarios). This per-well estimate of new economic activity is then used as an input to the IO Tables for Wales to estimate the direct/indirect and induced levels of gross value added and employment, with these impacts then aggregated to produce the scenario estimates based on numbers of bores, wells and pads.

Economic Impacts of Development in Wales

7.19 The following section presents the assessment of the economic effects in Wales of the potential development of unconventional oil and gas. The economic modelling uses the estimates of capital and operational spending for our combined scenarios of coal bed methane and shale gas developed earlier in the report (see Section 5).

7.20 For the purposes of examining economic effects in Wales the costs associated with the Low, Medium and High scenarios are examined as a block of spending over the period 2015-29 to provide an insight into the amount of economic activity in Wales that could be supported by developments. In common with other novel energy investments (and indeed to a perhaps greater degree) the timescale of investment and hence economic impact is uncertain.

7.21 Whilst the assessment assumes a 15-year aggregate and average annual employment and GVA impacts over this period, it is towards the end of this period (and beyond) that the investment will likely occur. Whilst the assessment has not discounted the economic impacts to return a net present value (mirroring other energy impact studies undertaken in Wales) it should be remembered that economic impact arising further in the future (and hence generally more uncertain) may be considered of lower value than more timely and certain investments.

7.22 The results from the regional economic modelling for the low, medium and high scenarios are found in Tables 7.1 to 7.3. Each table has two panels. The uppermost provides our estimate of total economic impact occurring over the whole period 2015-2029 under the lower and higher intensity development and operational spending ranges of the three separate scenarios. The bottom panel of each table shows the average annual economic impact over the period 2015-29 and here employment is in terms of full time equivalents (FTEs). Each table also reveals in broad terms where the economic effects will occur in the regional economy by sector

7.23 These estimates combine direct, indirect and induced economic effects (i.e. activity supported as the industries involved purchases goods and services in Wales themselves, and associated effects linked to the spending of wage income). Economic activity is measured in terms of Welsh output, gross value added, and employment. Employment is measured in terms of person years of employment.

7.24 Table 7.1 shows the results associated with the Business as Usual Low scenario and with this the associated estimate of total expenditure in the range of £9.21m to £13.05m for lower and higher intensity development. This reveals that these levels of activity would support between £4.4m and £6.5m of total output, and £1.7m to £2.4m of GVA in Wales. This output and GVA would equate to between 39 and 56 person years of employment supported in total.

7.25 Were these effects converted into a simple average annual effect over the period 2015-29, this would equate to £0.3m to £0.4m of output, and £0.1m to £0.2m of GVA per annum. In employment terms this would range from 2.6FTEs to 3.7FTEs. Note these are averages per annum over a long time period which have not been discounted here. Much of this economic activity would be supported in the manufacturing, energy and construction sector (i.e. over 50% of output effects and 40% of the employment effects), with much of the remaining activity focused in the private services sector.

Table 7.1 Total and Annual Economic and Employment Impacts – Low Scenario

	Low Scenario – Lower Intensity			**Low Scenario – Higher Intensity**		
Total Scenario Expenditure	£9.21m			£13.05m		
Retained Expenditure in Wales	£2.95m (32%)			£4.18m (32%)		
Total Economic Impact 2015-2029	Output (£m)	GVA (£m)	Emp Person Yrs	Output (£m)	GVA (£m)	Emp Person Yrs
Mining, Quarrying & Minerals	0.7	0.2	3	1.0	0.3	5
Manufacturing, Energy & construction	2.3	0.7	16	3.3	1.0	23
Distribution & Transport	0.3	0.2	6	0.5	0.2	8
Other Private Services	1.1	0.6	13	1.6	0.9	19
Public Sector	0.0	0.0	1	0.1	0.0	1
TOTAL	4.4	1.7	39	6.5	2.4	56
Average Annual Economic Impact 2015-2029	Output (£m)	GVA (£m)	Emp (FTEs)	Output (£m)	GVA (£m)	Emp (FTEs)
Mining, Quarrying & Minerals	0.0	0.0	0.2	0.1	0.0	0.3
Manufacturing, Energy & construction	0.2	0.0	1.1	0.2	0.1	1.5
Distribution & Transport	0.0	0.0	0.4	0.0	0.0	0.5
Other Private Services	0.1	0.0	0.9	0.1	0.1	1.3
Public Sector	0.0	0.0	0.1	0.0	0.0	0.1
TOTAL	0.3	0.1	2.6	0.4	0.2	3.7

7.26 Table 7.2 shows the results associated with the Medium scenario, with estimated expenditure ranging from £106.8m to £235m for the lower and higher intensity development assumptions. This shows that these levels of activity would support between £55.6m and £122.1m of total output, and £21.1m to £46.6m of GVA. This output and GVA would equate to between 510 and 1,080 person years of employment supported in total.

7.27 Converting these estimate effects into a simple average annual effect over the period 2015-29, this would equate to £3.7m to £8.1m of output, and £1.4m to £3.1m of GVA per annum. In employment terms this would range from 34FTEs to 72FTEs. Again much of the economic activity (an estimated 48% of output) under the Medium scenario would be supported in the Manufacturing, Energy and Construction sector, and 38% of the employment.

Table 7.2 Total and Annual Economic and Employment Impacts – Medium Scenario

	Medium Scenario – Lower Intensity			Medium Scenario – Higher Intensity		
Total Scenario Expenditure	£106.8m			£235.0m		
Retained Expenditure in Wales	£34.1m (32%)			£75.5m (32%)		
Total Economic Impact 2015-2029	Output (£m)	GVA (£m)	Emp Person Yrs	Output (£m)	GVA (£m)	Emp Person Yrs
Mining, Quarrying & Minerals	8.2	2.3	40	18.0	5.1	80
Manufacturing, Energy & construction	26.8	8.0	190	58.9	17.6	410
Distribution & Transport	3.8	1.8	70	8.3	4.0	150
Other Private Services	13.1	7.3	160	28.7	16.2	340
Public Sector	3.7	1.7	50	8.2	3.7	100
TOTAL	55.6	21.1	510	122.1	46.6	1,080
Average Annual Economic Impact 2015-2029	Output (£m)	GVA (£m)	Emp (FTEs)	Output (£m)	GVA (£m)	Emp (FTEs)
Mining, Quarrying & Minerals	0.5	0.2	2.7	1.2	0.3	5.3
Manufacturing, Energy & construction	1.8	0.5	12.7	3.9	1.2	27.3
Distribution & Transport	0.3	0.1	4.7	0.6	0.3	10.0
Other Private Services	0.9	0.5	10.7	1.9	1.1	22.7
Public Sector	0.2	0.1	3.3	0.5	0.2	6.7
TOTAL	3.7	1.4	34.0	8.1	3.1	72.0

7.28 Finally, Table 7.3 shows the results associated with the High scenario, and with this associated with a lower intensity spend estimate of £757.1m and a higher intensity estimate of £1,780.4m. This reveals that these levels of activity would support between £442.2m and £1,040m of total output, and £170.4m to £400.4m of GVA. This output and GVA would equate to between 4,010 and 9,410 person years of employment supported in total.

7.29 Converting these estimates into a simple average annual effect over the period 2015-29, this would equate to £29.5m to £69.3m of output, and £11.4m to £26.7m of GVA per annum. In employment terms this would range from 267 FTEs to 627 FTEs. Around 36% of the employment effects would be in the Manufacturing, Energy and Construction sector and with 28% of the employment effects within Other Private Services.

Table 7.3 Total and Annual Economic and Employment Impacts – High Scenario

	High Scenario – Lower Intensity			High Scenario – Higher Intensity		
Total Scenario Expenditure	£757.1m			£1,780.4m		
Retained Expenditure in Wales	£287.3m (38%)			£675.5m (38%)		
Total Economic Impact 2015-2029	Output (£m)	GVA (£m)	Emp Person Yrs	Output (£m)	GVA (£m)	Emp Person Yrs
Mining, Quarrying & Minerals	79.0	25.0	530	185.9	58.7	1,240
Manufacturing, Energy & construction	219.6	65.3	1,480	516.4	153.5	3,480
Distribution & Transport	29.7	14.3	530	69.9	33.6	1250
Other Private Services	93.9	53.5	1,130	220.8	125.7	2,650
Public Sector	20.0	12.3	340	47	28.9	790
TOTAL	442.2	170.4	4,010	1040	400.4	9,410
Average Annual Economic Impact 2015-2029	Output (£m)	GVA (£m)	Emp (FTEs)	Output (£m)	GVA (£m)	Emp (FTEs)
Mining, Quarrying & Minerals	5.3	1.7	35.3	12.4	3.9	82.7
Manufacturing, Energy & construction	14.6	4.4	98.7	34.4	10.2	232.0
Distribution & Transport	2.0	1.0	35.3	4.7	2.2	83.3
Other Private Services	6.3	3.6	75.3	14.7	8.4	176.7
Public Sector	1.3	0.8	22.7	3.1	1.9	52.7
TOTAL	29.5	11.4	267.3	69.3	26.7	627.3

7.30 Looking across the scenarios, the distribution of GVA effects varies between the Low and then the Medium/High activity scenarios. For example:

- Under the Low Activity High Intensity scenario an estimated 47% of GVA effects would be in the manufacturing, energy and construction sector, and an estimated 37% of GVA effects in private services.
- In contrast, under the Medium/High activity scenarios the GVA effects in the Manufacturing sectors fall to 38% in both cases, whereas the GVA effects in Private services fall to 35% under the Medium Activity High Intensity scenario to just 31% under the High Activity High Intensity scenario.

7.31 Therefore higher levels of expected activity would see a higher proportion of total GVA effects in other sectors as the supply side of the Welsh economy adapted to take advantage of the opportunities.

Summary

7.32 The analysis suggests the following:

- Under the low 'business as usual' scenario there is little additional economic impact
- The level of annual economic activity supported by the development activity varies significantly between the medium 'step up' scenario and the high 'step change' scenario, as the scale of activity and supply side of the economy adapts, that is:

  - Annual GVA ranging from £1.4m to £3.1m under the medium scenario to £11.4m to £26.7m under the high scenario
  - Annual FTE employment ranging from 34 to 72 jobs under the medium scenario to 270 to 630 jobs under the high scenario.
- The generation of wealth and employment across a broader range of sectors in the Welsh economy under the higher scenarios, as the suppliers adapt to a limited degree to the opportunities which arise.

7.33 In concluding this section it is important to revisit some of the wider uncertainties which might limit the potential for unconventional gas production occurring in Wales. At the outset production conditions in Wales would be very different from that in the US, and even were the primary production conditions comparable, developers in Wales would face a very different mix of planning constraints to those that US firms have typically faced. In this context the information revealed in Tables 7.1 to 7.3 should be viewed as illustrative and in the opinion of the authors the High activity scenario is on balance less likely to occur in this timescale given the wider uncertainties attendant on development in the sector.

8. Employment and Skill Needs & Opportunities

8.1 The development of onshore oil and gas in the United Kingdom and Wales will create a series of skills related challenges for both industry and Government in Wales and elsewhere. This has led to a number of research studies and there is now a good appreciation of the spectrum of skills needs related to exploration, drilling and exploitation. But at the same time, the scale of these challenges is open to a degree of uncertainty around, for example, the pace of sector development and competition for skills. On this later point, there is a strong degree of commonality with offshore oil and gas and with the chemicals industry, however these industries are already experiencing skills shortages of their own.

8.2 The growth of unconventional gas in Wales could also provide an opportunity to create additional skilled and well-paying employment, possibly in communities with low levels of employment.

8.3 This section considers the following issues:

- The range of skills required by the unconventional gas sector and its supply chain
- The potential scale of requirements
- The existing and planned skills infrastructure, both at a UK and Wales level
- The issue of competing demands for skills and the implications.

Range of Skills Requirements

8.4 Just as in standard supply chain analysis, the conventional way to understand skills requirements is to break down job roles and contexts for individual rigs/pads, to look at different phases of development, and to aggregate individual profiles into an industry wide forecast. This is the method used in the highly influential study of the Marcellus Shale field in the United States[118].

8.5 As explained in the previous section, a very large proportion of the total workforce and skills mix is required during the drilling phase, while a much smaller workforce is needed for the longer production phase. Before drilling or exploitation can begin however, there is a pre-drilling phase involving exploration, leasing, surveying, engineering, and permitting of the extraction site. During the exploration and drilling phases, workforce requirements are generally at their peak. In the United States, it was found that these two phases constituted 98% of job requirements[119]. By contrast production phase jobs were relatively light. Post production and decommissioning jobs have received slightly less attention in the existing literature, probably because this stage has not yet been reached in many current shale gas or CBM field and the availability of economic and employment studies is limited.

8.6 The full spectrum of skills requirements can be illustrated through the use of occupational matrices, an example of which is provided below for the post drilling, operational; and decommissioning phases. Matrices for other phases of development are provided in Appendix B.

[118] Marcellus Shales Education and Training Centre (2009) Marcellus Shales Workforce Needs Assessment, Employment Study.

[119] Jacuet, J, (2011) Workforce Development Challenges in the Natural Gas Industry, Working Paper Series, City and Regional Planning, Cornell University.

Table 8.1 Production Phase Occupational Matrix

Natural Gas Extraction Education / Job Matrix Post-Drilling Phase				
	Associated Jobs	Secondary/ Career and Technical Centres	Work Experience/ Certification	Post-Secondary/ Higher Education
Natural Gas Production	Petroleum Engineers		X	x
	Heavy Equipment Maintenance Tech		X	x
	Operator		X	
	Compressor Operator		X	x
	Service Rig Operator		X	
	Production Engineer		X	x
	Equipment calibration		X	x
	Communications Tech offsite monitoring		X	x
	Production Foreman	x	X	
Reclamation	Plugging Crew		X	x
	CDL Drivers	x	X	
	Site Management		X	x
	Landscapers-architect	x	X	
	Environmental Inspection		X	x
	Civil Engineer		X	
	Government officials		X	
Overall	Inspectors	x	X	
	Sewage treatment		X	x
	Lobbying		X	x
	Community Affairs/PR		X	x
	Calibration Officials		X	
	Corrosion Technicians		X	x
	Environmental Health & Safety		X	x
	Purchasing		X	x
	IT Tech		X	x
	Local Liaison		X	
	Office Management		X	x
	Office support-admin-non tech	x		

Source: Marcellus Shale Education & Training Center, Marcellus Shale Workforce Needs Assessment, 2009, p. 35

8.7 Broadly speaking, the spread of job requirements across the various phases requires more high level and specialised skills at the exploration and post-production phases. Without going into details of total demand, the recent Ernst and Young report suggested the following:

- For highly skilled petroleum engineering and geoscientific roles, the UK's historically strong position has been eroded by the economic downturn and an ageing workforce.
- There are likely to be difficulties in recruiting skilled blue collar roles for drilling and completion, particularly when faced with competing demands from the offshore industry.
- There is a shortage of hydraulic fracking engineers in Europe, simply because the market is too immature.
- The existing regulatory and approvals workforce in the UK is likely to be able to cope with any demand relating to future permitting work.

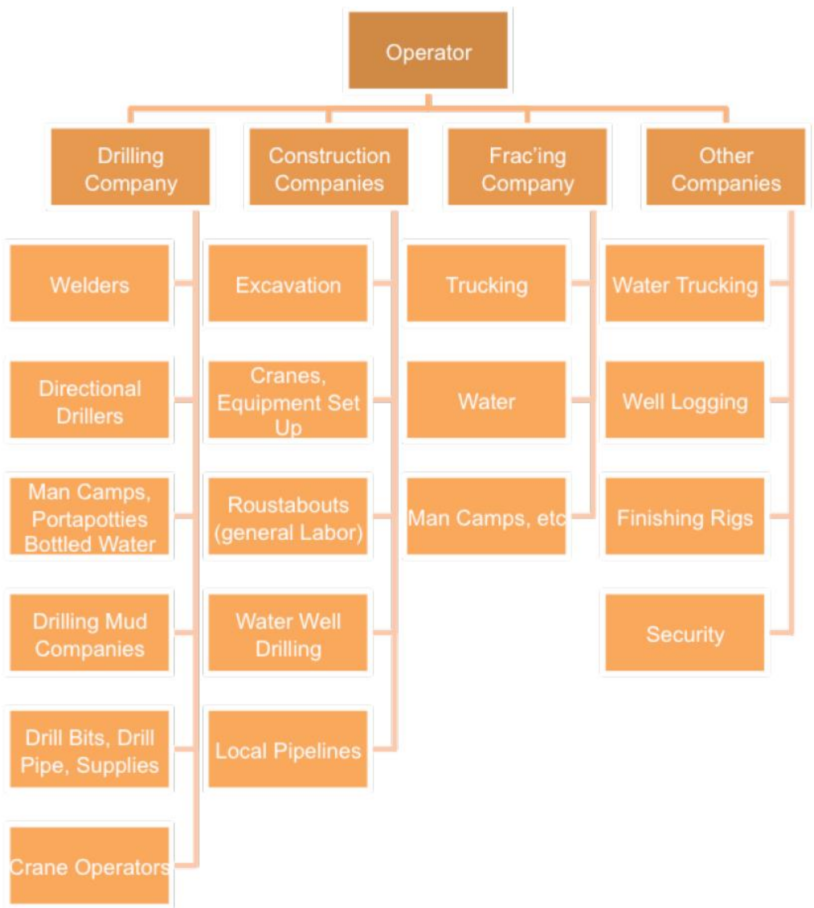
8.8 For Wales, and following on from related discussions in the supply chain analysis, the suggestion is that for any development of indigenous unconventional oil and gas, higher level skills and experience *are more likely* to be imported from either the UK offshore sector and its service providers, or the wider international labour market. This is because workers' higher level skills in these areas are more closely aligned to the needs of UK unconventional oil and gas.

8.9 In the former case, offshore specialists are likely to be able to adapt core competencies and requirements to new demands; in the latter case, international recruits are likely to be already versed in techniques and knowledge, but will require some support in coming to terms with the UK regulatory requirements. It follows therefore that skills needs within Wales are likely to centre on technical occupations and wider support roles (tanker drivers, construction etc.). There may be some scope for workers in Wales to contribute to activity outside of the country (e.g. the North West), but this will be dependent on the nature and scale of exploitation elsewhere, and the strength of the Welsh supply base.

The Scale and Source of Requirements

8.10 The scale of workforce requirements for both Wales and the UK is a function of the number of sites developed for unconventional oil and gas production. A related issue is whether UK activity will deliver sufficient critical mass to make indigenous skills provision a workable solution. The Ernst and Young study forecast a workforce requirement of up to 64,500; estimates used elsewhere in this report are slightly less dramatic.

Figure 8.1 Industry Sub-Contracting Structure



Source: Cornell University, Working Paper Series: A Comprehensive Economic Impact Analysis of Natural Gas Extraction in the Marcellus Shale: Workforce Development Challenges in the Natural Gas Industry, 2011

8.11 Consultations undertaken as part of this exercise have shown some scepticism about whether the UK will achieve enough volume to require the development of certain higher level skills. Several consultees indicated that the most likely outcome would see operators importing experience and development. This trend will be accentuated by the wide array of sub-contracting arrangements that are likely to typify the sector. Based on existing oil and gas practice, an operator may contract out for the services of an excavator, a hydro-fracturing company, a well-completion company, and each of these may, in turn sub-contract out such tasks as forestry, gravel, drilling supplies and services, cementing and environment management. These types of structures will apply equally to CBM and gasification.

8.12 This suggests that the higher level skills specialisms are likely to be filled by individuals or companies already at work in either offshore services or related disciplines. Since Wales does not has a specialism in these areas, local companies would struggle to match the level of service provision that (say) Scottish based companies could provide.

Existing and Planned Skills Infrastructure

8.13 The currently available energy and engineering based skills infrastructure in Wales has been investigated in some detail by EU Skills working in collaboration with Miller Research. Their recent (August 2013) study, albeit focused on the renewables sector, provided a useful snapshot of current public and private skills provision and current skills gaps which might affect the unconventional oil and gas sector. They concluded that while current provision matched wider UK levels, there was no coherent skills planning infrastructure in place to address current shortfalls and future strategic challenges. They also expressed some concerns about the quality and expertise of some providers and trainers, and suggested that local colleges needed to work more closely with employers to develop transferable standards and qualifications.

8.14 The EU Skills work echoed many of the findings of Offshore Petroleum Industry Training Organisation (OPITO) and Cogent sector specific skills surveys. In particular, the emphasis on wider STEM skills and engineering related issues would be familiar to both employers and commentators. However, there is nothing in the analysis to suggest the Welsh skills infrastructure is better placed to meet potential demands related to unconventional oil and gas. UK Central Government and UKOOG, the industry trade body, clearly believe offshore service companies and the oil and gas sector will provide the basis for skills expansion in this area.

8.15 The recent decision to appoint OPITO to modify existing offshore vocational and other standards for onshore development shows that in fracking at least, skills development is likely to centre on the existing offshore sector and its service companies. Because of this, we believe that skills development and funding is more likely to be steered towards areas that already specialise in offshore activity.

8.16 There has also been a recent announcement concerning the creation of the £1.5 million National College for onshore oil and gas skills. Jointly funded by the Department for Business, Innovation and Skills and the onshore oil and gas industry, the National College will draw together a number of leading education and training institutions and industrial partners to deliver training programmes which will be designed to meet the onshore industry's future skills needs. The press release from UKOOG which accompanied the announcement made the following telling announcement, *'Building on the UK's world-leading offshore heritage, the National College will help the UK to become an international centre of excellence for onshore operations. Its aim is to train the next generation of onshore oil and gas engineers and other specialists, providing first class qualifications and career opportunities for young people*'.

8.17 The National College will operate a 'hub-and-spoke' model, with headquarters in Blackpool. It will deliver a comprehensive range of qualifications up to Level 6, with facilities including a drill simulator and emergency control simulator. Other institutions will be participating in the National College include:

- The University of Chester's Faculty of Science and Engineering at Thornton Science Park, which will deliver a number of industrially informed undergraduate and postgraduate degree courses (Level 4 to Level 7) as well as specialist masters, MRes and PhD programmes. In addition, the University of Chester will undertake research and technology transfer in the areas of process improvement, computational modelling and simulation, environmental monitoring and data and information management.
- Redcar and Cleveland College is currently working with the Local Enterprise Partnership, Tees Valley Unlimited, to create a new £7.4m Oil and Gas Academy for the North East, supported by the oil and gas sector and a Local Growth Fund bid. Teesside Oil and Gas Academy will deliver a range of accredited and specialist bespoke courses up to Level 5, and the College will provide additional specialist provision as part of the National College.
- Highbury College Portsmouth's Centre of Excellence in Construction, Energy & Sustainable Technologies provides a comprehensive range of accredited and bespoke courses to support entry to and progression in the onshore energy industry. Courses cover construction, environmental technologies, health and safety, and leadership and management. Highbury College is also developing a strong partnership with the Southern Alberta Institute of Technology, an acknowledged global leader in this industry and located in Calgary, Canada's hub for oil and gas operations.
- UK based engineering company Weir Group PLC – the world's largest supplier of hydraulic fracturing equipment – their supply chain and the University of Strathclyde – the UK's centre for hydraulic fracturing pump design – will partner with the National College to provide access to the latest industry best practice and the latest research and technology. Weir and Strathclyde will develop simulation systems the National College can use for training and accreditation, and will support the creation of UK industry standards for safe and responsible hydraulic fracturing operations.

8.18 This initiative is a largely an English project, but it could enable Welsh employers and operators to benefit from College activities. Funding issues aside, Central Government consultees indicted that other institutions could be invited to participate in College programmes, even if they were based in other devolved nations.

Implications of Competing Uses

8.19 While the future shape and source of vocational and higher level skills provisional for unconventional oil and gas is becoming more certain, there will be subsidiary skills issues which Wales will need to be aware of. These concern the impact of developing onshore resources for related service activities (e.g. tanker drivers, construction), and wider implications for STEM type industries.

8.20 We believe that service activities are more likely to be provided by local companies. Here the skills challenges are largely scale based, and will require the adaptation of existing standards and skills provision to enable contractors to work safely and responsibly on-site. A variation of the successful Nuclear Skills Passport may be required to meet this demand[120]. In concert with these changes, existing skills training may have to be expanded if indigenous unconventional resources are developed.

8.21 The development of gasification, CBM or fracking may also steer recruits away from established sectors in chemicals, engineering and related fields. The impact on existing Welsh companies reliant on STEM recruits may be exacerbated if unconventional gas activity succeeds in lowering chemical feedstock prices. Feedstocks are a key input in many advanced manufacturing and process activities, and could provide the basis for a major expansion (as has happened in the US chemical industry).

[120] See https://www.nsan.co.uk/what-nuclear-skills-passport

Research undertaken by Cogent, the Sector Skills Council, indicates that the chemicals and onshore refining sector is already suffering from age related recruitment and retention issues. Left unchecked, future expansion in this sector will lead to unintended spill-over effects on the wider STEM related labour market.

Summary

8.22 The scope of the skills challenges related to the development of unconventional oil and gas are understood fairly well by industry and policy commentators. Higher level skills are more important in the exploration and post production phases, while the sector needs the support of a wide range of vocational and blue collar technical occupations throughout the operational life of any site.

8.23 What is less well understood is the degree to which skills demand will be conditioned by the existing offshore operations and international service companies. Given current industry structures, it seems more likely that higher skilled workers will be procured internationally or through existing service providers which operate (and indeed recruit) at a national level. This leaves some scope for the provision of locally sourced technical and vocationally qualified workers, particularly in *locally* procured services. This certainly could have an impact in creating additional skilled and possibly well paid employment in areas with low levels of employment.

8.24 The evolving skills infrastructure in unconventional oil and gas is heavily predicated on adapting existing offshore standards and roles. There is no reason why Welsh providers and institutions could not play an important role in this process, but currently there is little sign of any strategic engagement.

9. Other Potential Economic Impacts

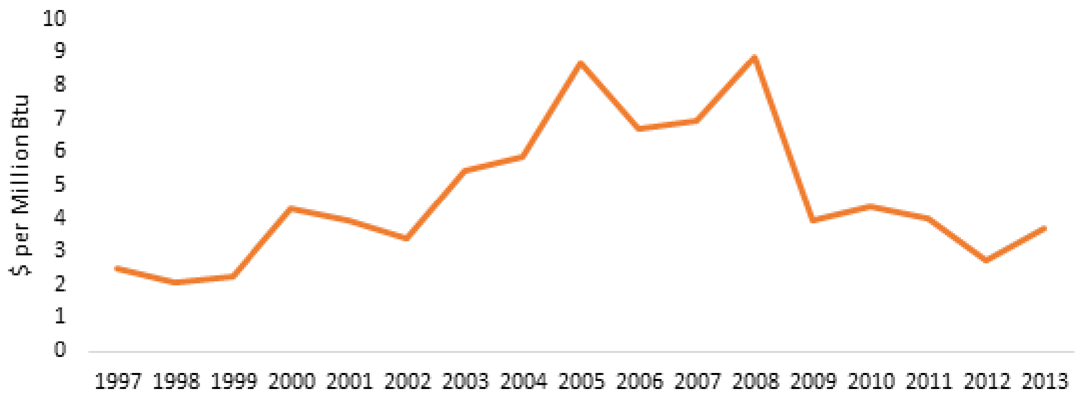
9.1 This section considers the potential for a wider range of economic impacts associated with the emergence of unconventional gas and hence a new source of energy within Wales. This includes economic benefits which could arise for energy generators or companies located within Wales as a consequence of additional local and potentially cheaper sources of energy.

9.2 The analysis also considers the potential economic impacts of unconventional gas development on assets and resources in Wales including electricity transmission and gas networks, associated infrastructure and water resources. There is a limit to how far this assessment can consider these types of impacts given little is currently known about the potential locations for development, although the development scenarios provide a framework for considering high level impacts. The planning and regulatory process will provide the mechanisms for identifying scheme specific effects.

Energy Price and Sector Effects

9.3 There has been some debate on how far significant development of the unconventional gas sector in the UK could provide benefits for firms in the UK (or Wales) which are either energy intensive in their own right or which use gas as a feedstock to produce various chemicals. This interest has been stimulated by the experience of the US, where the expansion of shale gas production has already seen sharp falls in the price of natural gas and with this one factor leading to increased investment in the US chemicals sector.

Figure 9.1 US Natural Gas Spot Price, 1997 – 2013



Source: US EIA

9.4 PwC (2012)[121] estimated that the US chemicals industry had invested some $15bn thereby increasing capacity by one third and placing some US firms in a position to globally supply feed stocks. Undoubtedly such investments would have spillover effects to other manufacturing sectors in the US, with again PWC (2012) citing the ability of manufacturing firms to employ relatively lower cost chemicals to make plastic-based substitutes for other materials, and with the availability of cheaper energy and chemical inputs leading to some US firms bringing back operations to the US that were previously undertaken overseas (i.e. reshoring of selected manufacturing activity).

9.5 Rising energy costs pose a particular problem in the Welsh industrial landscape. Despite the region's low GVA, Wales has amongst the highest energy use (per capita and per unit of GVA created) of UK regions. Wales has significant industrial capacity in energy intensive activity including the steelmaking

[121] PWC (2012) Shale Gas: Reshaping the US chemicals industry.

sector, oil refining and basic chemicals sectors. These sectors have come under real economic pressure with, for example, this year seeing the decision of Murco at Milford Haven to cease refining oil. Moreover, these industries face indirect costs arising from UK and European g energy and climate change policies. Each of these sectors are major employers in Wales, with relatively high quality employment, sometimes in parts of the regional economy with significant socio-economic challenges. The investment by these sectors could lead to significant regional economic returns directly, and indirectly as these same sectors purchase more in the regional economy. Added to this Wales also hosts a number of gas-fired power stations which are potential purchasers of gas from unconventional sources.

9.6 However, our review of research leads to the conclusion that the scale of economic effects (both current and forecast) within the US economy are unlikely to represent any benchmark for UK or Welsh regional effects. Several issues need to be considered:

- Notwithstanding uncertainty of the level of UK (and indeed European) unconventional gas reserves, there is a strong expectation that the costs of production will be relatively high for UK developers.
- While UK industry may benefit from US exports of gas it is important to recognise that the transport of gas (i.e. LNG) is relatively expensive, with these additional costs reducing part of the cost advantage of unconventional gas supply.
- The UK already imports significant amounts of natural gas. UK shale gas production is therefore widely perceived to have a limited future effect on UK gas prices.

9.7 In summary, the US comprises a largely self-contained gas market and one where the exploitation of shale and other unconventionals represented a significant shift in the supply of fuels and feedstocks. Neither of these is currently true for Wales or likely to occur in the timescale considered within this study. Wales is part of a UK electricity and gas grid, and operates in a gas market where prices are largely set at a European level and the cost of transportation (along the gas grids at least) is low. Added to this is uncertainty about the location of any processing which may be required for Welsh shale gas/methane prior to use, and the attitude of gas owners to contracting for product sales across wide geographies and to the highest bidder (as is happening already in North America with unconventional supplies becoming more export oriented).

9.8 In short, the likelihood of Welsh origin gas being used in Wales is not high, and even where this is the case it will be under UK or EU market prices. This is not to exclude specific, mutually beneficial two party contracts (as was the case between Wylfa Nuclear Power Station and Anglesey Aluminium, and also more recently plans for Ineos at Grangemouth in Scotland to invest in the shale gas resource). However, the geographically distributed pattern of extraction activity and the more uncertain nature of shale exploitation (for example links to the scale of the exploitable resource, planning issues and other development uncertainties) arguably limit the potential for this regional partnering.

9.9 To make a difference (independent of UK or other unconventional development) Welsh production would effectively have to be substantial enough to affect the gas price at a far wider spatial scale than Wales itself. Even here, Welsh consumers or businesses would be on (largely) a level playing field with other purchasers.

9.10 In consequence, while Wales has relatively high levels of employment in energy intensive sectors, it is unlikely that the extent and the timing of shale gas production would lead to any significant investment effects.

Infrastructure and Resource Effects

9.11 This aspect of the assessment considers the impact of unconventional gas development on assets and resources in Wales including electricity transmission and gas networks, water supply and waste water treatment and associated infrastructure, in particular transport networks.

Water Resources

9.12 Water is required in some forms of unconventional gas drilling and extraction activity, in particular the fracking of shale seams. The resource is required primarily as part of the initial fracking process, as well as any refracking of a well in order to extend its productive life (usually once but possibly twice). The use of water as part of the extraction process is much less of an issue for coal bed methane (due to less need to frack the seams), although there may be waste water which needs to be managed appropriately (water can be produced through de-watering during the exploration and production process).

9.13 The particular relevance of this consideration for this study is due to the following:

- The extent to which the availability and access to sufficient water could constrain the development of the unconventional sector in Wales
- Alternatively, the potential for the scale of demand to limit the access to this resource by other productive sectors
- The scope for the treatment of waste waters to impose a burden on existing wastewater treatment infrastructure capacity.

9.14 Ricardo-AEA report for the Environmental Agency estimates that the water requirement for hydraulic fracturing of 2,592 shale gas wells with a 50% refracturing rate amounts to 0.1% of total non-domestic water use, or 10% of the water used in mining/quarrying in 2006/2007. While the water resource availability is unlikely to be a constraint, the evidence from the IoD (2013) report identifies water treatment facilities as a minor barrier. The report estimates that the amount of flowback water could amount to 1.6 million cubic metres, representing 0.05% of the total sewage production in the UK. While the water treatment infrastructure in the UK is extensive, the report highlights that new plants are likely to be needed if the unconventional oil and gas industry develops at a commercial scale.

9.15 To give some sense of scale to the requirement, we have used the development scenarios to test the scale of the resource which might be required, informed by industry practice in its use of water and the research literature. We have drawn on the assumptions contained in DECC's SEA report on water use in particular:

- Between 10,000 and 25,000 cubic metres of water being required for hydraulic fracturing of each well and each well being re-fractured once
- Between 30% to 75% of the water injected during fracturing returning as flowback
- Flowback can be recycled for use, with treatment providing another source of economic impact. However, like the DECC assessment, it is assumed that flowback water is not reused and will need to be treated and that this treatment has to be offsite
- Between 14-51 vehicle movements a day during Stages 2-3.

9.16 Under the various scenarios the volumes of water use and wastewater for treatment would be around:

- Low scenario – the scenario requires minimal water as an input and generates modest wastewater for treatment compared to the other two scenarios (for this reason it is not presented here)

- Medium scenario - a maximum of 0.6 million cubic metres of water in total and a maximum of 0.52 million cubic metres of waste water over the period
- High scenario – a maximum of 4.8 million cubic metres of water in total and a maximum of 3.8 million cubic metres of waste water over the period.

9.17 To put this into context, Welsh Water supplies on average 0.85 million cubic metres of fresh water every day. This means that under the high scenario the total volume of water required would represent 1.5% of Welsh annual supply. Whilst this is a small part of the current overall supply, the ability to supply and actual impact on local infrastructure would depend on: the location and number of development pads in particular areas; the availability of existing water resources and the volume of water presently extracted by existing users in that area; the volume of wastewater that can be recycled and used as fracturing fluid.

9.18 The maximum wastewater requiring treatment under the high scenario is equivalent to 0.1% of UK annual wastewater. Whilst our conclusion of the potential burden this treatment activity places on wastewater treatment infrastructure capacity in Wales depends on the location[122], this volume is unlikely to place a substantial burden on this existing infrastructure as a whole. However, as noted in DECC's SEA, '*Depending on where this requires treatment, this volume of wastewater could place a substantial burden on existing wastewater treatment infrastructure capacity*' and as a consequence the potential activity which emerges through the 14th licencing round was '*assessed as having a significant negative effect on the waste objective*'. In addition, the Environmental Statement for Caudrilla's proposal for exploratory drilling and fracking at Preston New Road[123] concludes that the generation of flowback waste would have a significant effect given the availability of local treatment capacity, although this could be mitigation through transportation of these wastes to other facilities in the North West of England.

9.19 It should be born in mind that there is potential for on-site treatment and reuse to reduce the volumes of wastewater generated for any development within Wales, and hence to lessen any effects on off-site treatment infrastructure capacity if this were required.

Transport Infrastructure

9.20 There will be a range of vehicle movements that occur during the well site construction, production and decommissioning which may impact on local communities adjacent to sites or on routes to and from the site. The traffic is associated with the delivery of equipment (some of which is bulky in nature) and materials (including high volume inputs such as water), the movement of wastewater and possibly gas, as well as the final removal of equipment and related facilities.

9.21 The actual vehicle movements will depend on a number of factors including: the number of wells drilled and their phasing; the volumes of water needed; how water is sourced and whether it is tankered to the site; the volumes of waste and wastewater generated; the methods and locations of waste treatment; and the manner in which the extracted gas is removed from the site, whether this is by tanker or pipes.

9.22 If not controlled in an appropriate manner, the additional vehicle movements can generate a variety of effects which can have economic and social consequences and are hence relevant to this assessment. These effects include for example:

[122] Flowback from the Preese Hall exploratory well in Lancashire was stored on site and subsequently transported to the Davyhulme wastewater treatment work (WwTW). This WwTW treats other industrial effluents from the Manchester area and was considered by the EA as capable of dealing with the levels of minerals contained in the flowback from the Preese Hall site. See Environment Agency (2011) Shale Gas North West- Monitoring of flowback and Environment Agency (2013) Onshore Oil and Gas Exploratory Operations: Technical Guidance, Consultation Draft for further information.

[123] Cuadrilla Bowland Ltd (2014) Environmental Statement, Temporary Shale Gas Exploration at Preston New Road Lancashire.

- Congestion on local roads that lead to the site, depending on site access, timing and existing traffic flows; and
- Noise, vibrations and dust in the vicinity of the site and local access roads.

9.23 The evidence from the US has pointed to a variety of negative effects in locations with more intensive extraction activity, due to the scale of activity as well as the nature of many of the roads (where there has been extensive use of unpaved or low grade roads). In contrast, the local road infrastructure in Wales is judged to be more wide spread and of a higher quality compared to the US. As a helpful guide, the DECC SEA concludes that under their higher intensity development scenario (i.e. the higher number of wells per shale gas pad), the number of vehicle movements will be highest during the initial exploration and subsequent development of the pad but falls sharply during production. The SEA concludes that at its peak, the number of HGV movements per day per pad are likely to be between 17 and 51 depending on assumptions regarding resource requirements, flow back water created and the scenario considered. The assumed level of drilling and extraction intensity is broadly comparable to the higher intensity assumption in this report.

9.24 Clearly, the effects on the local residential and business communities will be highly dependent on the location of sites and access roads in relation to these communities, as well as the frequency, timing and routing of vehicle movements. Larger urban communities would in general be more able to absorb this level of additional traffic, although with a potential requirement for mitigation in the forms of the development of a transport plan, management of vehicle movements and the use of alternative routes to and from the site. The high volume could be a more significant issue in smaller communities with limited scope for the use of alternative routes. However, these matters would need to be considered on a case by case basis as part of the planning and regulatory process.

9.25 There is also the potential for a crowding out effect that could occur if the local large capacity trucks and tankers were to be taken up by a rapid expansion in the unconventional gas sector, having a negative impact on their usual customers. However, the scenarios do not suggest that the scale or pace of development would lead to impacts of this nature.

Gas and Electricity Network Infrastructure

9.26 This section considers the consequences of the development of unconventional gas in Wales for the ancillary infrastructure required to transport the extracted gas by pipeline to the main gas network or its use in power generation as part of the energy mix (and any increasing in capacity to enable this).

9.27 Gas is the main energy source used for electricity production within Wales, accounting for 10,670 gigawatt hours in 2011 (39% of total production). The level of production from gas has fallen by over a third (-38%) since the start of the recession (2007), much faster than the overall fall in electricity production (-17%). The decline is assumed to be due to a mix of factors including an overall fall in demand due to the economic recession, as well as the relative increase in the costs of gas over this particular time period. The overall gas generation capacity has remained fairly constant over this period, suggesting that load factors have declined.

9.28 For both shale gas and CBM, there are options to use the gas produced in on-site electricity generation facilities which feed directly into the grid or to feed the gas into the national transmission network. The former option is possibly the less intrusive and costly compared to constructing pipeline connectors to the national transmission network - this is a common approach for CBM and in other countries, which do not have a national gas network. However, this will depend upon a range of factors, including the nature of the location and site and proximity to the national transmission or distribution network.

9.29 Wales has significant gas fired generation capacity with an estimated 5.05GW of installed capacity in 2014. Much of this capacity is potentially in close proximity to the likely sources of extraction and production (both the 13th round PEDLs and the areas being let as part of the 14th round). These include:

- North Wales – Deeside (515 MWs), Connahs Quay (1,380MWs)
- South East Wales – Severn (848MWs), Barry (140MWs), Baglan Bay (510MWs), Pembroke (2,180MWs).

9.30 Many of these existing power stations will be able to use new sources of unconventional gas provided through the transmission network, subject to the availability and price of these sources compared to others. Should significant shale gas finds reduce wholesale gas prices, these plants may be employed at higher levels of capacity and more quickly displace other forms of fossil fuel generation in Wales. However, the increased employment impacts in gas generation would be negligible given the very high capital intensity of these facilities. In terms of effects on renewables generation trends in Wales, the focus here would be on how far significant finds of shale gas might influence future negotiations with renewables developers surrounding the strike price of delivered electricity.

Summary

9.31 Within the framework of analysis adopted here it is difficult to examine the impacts of significant shale gas finds in Wales (and wider UK/overseas) on other sectors of the regional economy that are energy intensive and effectively 'downstream' from shale gas production. However, there are a series of industries in Wales that could use produced gas as a feedstock including the Valero Oil refinery at Pembroke Dock and Tata Steel at Port Talbot. However, we expect any effects on these and similar industries in terms of cheaper chemical feedstocks or cheaper gas for fuel to be related more to scale of activity in the UK and overseas as opposed to being linked to the scale of accessed shale gas resources in Wales. Moreover, the benefit of cheaper input prices might impact primarily in terms of safeguarding employment in these sectors rather than providing a boost for new inward investment, particularly given the extensive global capacity in these sectors and the record of recent closures in Wales (for example, the closure of Murco to oil refining).

9.32 The assessment has also considered the potential implications of the growth of unconventional gas extraction for resources and infrastructure within Wales, including water supply and waste water treatment, transport infrastructure and ancillary infrastructure required to transport the extracted gas by pipeline to the main gas network (or its use in power generation as part of the energy mix and any increase in capacity to enable this).

9.33 This aspect of the assessment has been undertaken at a high level given the uncertainties over the precise locations of future development activity and how these relate to the types of infrastructure being considered. The analysis suggests that only the level of potential activity assumed under the high scenario (and the high intensity range within this scenario) could any infrastructure constraints at this spatial level of analysis be encountered, with the main constraints being around the supply of water and wastewater treatment (associated with flowback). However, this will depend on the location and scale of development compared to the available supply and associated capacity of the infrastructure, which will need to be tested through specific environmental impact assessment for proposed exploration and production activity. There could also be other infrastructure constraints at specific locations.

9.34 Whether this has an impact on the need for and nature of the sag network infrastructure in Wales is currently unclear. Developers will have various options for the use of the gas, including the use of on-site generating facilities which feed electricity into the grid or feeding gas direct into the national gas network with the need for the associated on and off-site infrastructure.

9.35 Wales has significant gas fired generation capacity, an estimated 5.05GW of installed capacity in 2014 such that were significant shale gas or CBM finds to reduce wholesale gas prices these plants may be employed at higher levels of capacity and more quickly displace other forms of fossil fuel generation in Wales. However, the increased employment impacts in gas generation would be negligible given the very high capital intensity of these facilities. In terms of effects on renewables generation trends in Wales the focus here would be on how far significant finds of shale gas might influence future negotiations with renewables developers surrounding the strike price of delivered electricity.

10. Local Community Impacts

10.1 This section considers the range of socio-economic benefits and disbenefits that the development of unconventional oil and gas may have on the local communities in proximity to the development. The main types of benefits include:

- Access to employment and related training directly associated with the onsite activity, as well as indirect employment opportunities associated with the supply chain and induced employment linked to wider expenditure effects arising locally
- Additional income which host communities receive as a consequence of the voluntary scheme proposed by UKOOG.

10.2 There are of course also a range of potential economic and social disbenefits, ranging from the displacement of existing business activity, the attraction of skilled workers away from local businesses, traffic congestion, and additional demands on social and community infrastructure. There is also the potential for other impacts on recreation, tourism and community life which might be associated with visual impacts, noise impacts or impacts on air quality.

10.3 The local context will be important in determining many of these impacts and hence there is limited scope to examine these in this assessment, other than at a fairly high level at this stage in the development of unconventional oil and gas in Wales. The assessment does not cover other potential community impacts such as health impacts.

Local Access to Employment and Skills

10.4 The main employment impact estimates set out in Section 7 combine direct and indirect estimates of employment supported in Wales under the various development scenarios. Some, but by no means all, of this employment will be available to local communities as opposed to workers in areas outside of these communities (including peripatetic workers who will typically travel with the specialist drilling and related equipment from one site to another).

10.5 The critical issues for Welsh communities which host the developments are the extent to which:

- Local residents are able to access the direct and supply chain jobs created on or close to the production site
- Supply-chain opportunities are captured by local businesses (who in turn will employment local people)
- The spending by those local residents and businesses who benefit from local developments are retained in the local area, supporting other local businesses and employment.

10.6 The fundamental challenge which arises in this regard is that the unconventional gas sector is at a very early stage of development in the UK (let alone Wales) and the limited supply of relevant skills currently within the UK to meet the expansion of the sector. It is highly likely that outside expertise will initially be needed to assist the growth of the sector and its supply chain. This will reduce the scope for local residents to access some of the job opportunities which will exist on or close to the production sites.

10.7 The evidence which informed the economic impact estimates assumes that in practice the opportunities for local companies to access supply chain opportunities would be limited to a fairly narrow range and value of goods and services. This reflects a number of factors including:

- The current structure of the business base across Wales as a whole and the presence of technology, skills and expertise which would enable these firms to realise the opportunities

- The likelihood that firms outside of Wales benefit from a first mover advantage as development activity occurs at a faster rate in other parts of the UK, but also the scope to tap into more relevant skills (for example, firms in the conventional oil and gas sector supply chain).

10.8 The types of employment opportunities which will arise for the local workforce in close proximity to the exploration and production sites during the exploration phase will include:

- Direct – security staff, haulage (drivers), various construction trades (linked to preparation of pads and related facilities), etc
- Indirect/induced – support for employment in hospitality trades, including accommodation providers, bars and restaurants, as well as other service sectors such as retail and private transport providers, etc.

10.9 Whilst the overall employment supported during the production phase will be limited in scale, there will be direct opportunities for employment amongst the local communities. The local workforce and supply chain base can be built up over time to ensure that local residents secure direct opportunities during the production phase: these would include ongoing maintenance jobs, jobs associated with the installation of midstream infrastructure (eg pipelines, connection to the grid). However, this phase will not have the same scale of mobile temporary workers and hence the support for local employment in the service sector will also be less.

10.10 The Environmental Statement for Caudrilla's application for exploratory drilling and fracking at Preston New Road Lancashire concludes that '*employment generation, with direct employment for initial exploration wells predominantly drawn from beyond the local area, but with indirect and induced effects from local spending and the influx of population on Site (local industry, hotels and subsistence for example)'.*

10.11 Ultimately the extent of employment opportunities in local communities which host unconventional gas sites will depend on the scale of local drilling and production activity, as well as the potential for these communities to also attract related administrative functions and parts of the supply chain. Whilst the formers opportunities may be limited in scale and scope, the latter will be unlikely for most communities.

Community Benefit Packages

10.12 Host communities will also be able to benefit from community benefit payments. These payments are a voluntary arrangement proposed by the industry through UKOOG and not part of the planning process. Section two outlines the proposed Community Engagement Charter which has been outlined by UKOOG including: £100,000 per well site where hydraulic fracturing for shale gas takes place; as well as a share of proceeds at production stage of 1% of revenues, allocated approximately 2/3rd to the local community and 1/3rd at the county level. In addition, the UK Government has proposed a one-off voluntary community payment of £20,000 for each unique lateral well that extends by more than 200 metres laterally. These only currently apply to shale gas, with not similar arrangements, voluntary of otherwise for coal bed methane or gasification.

10.13 An analysis of the value of these arrangements for local communities is presented below. The variable component of the Charter would depend on the price of shale gas at any point in time. Based on the current price and DECC's projections of future gas prices up to 2030, the value varies for the different scenarios:

- High scenario – between £14.89m and £34.61m in total over a fifteen year period or £1m to £2.3m per year (£0.12m to £0.28m per pad per year)
- Medium scenario - £1.86m and £4.32m in total or £0.12m to £0.29m per year (and £15k to £36k per pad per year)

- Low scenario – this does not include any new shale gas activity and hence there are no specific community benefit payments associated with it.

10.14 Clearly this could be a sizeable financial benefit for the host communities. It is difficult to predict the location of the pads other than that they will be located in the license areas. Although there is the potential for a degree of clustering of more than one pad in proximity to particular communities, this will depend upon the nature and accessibility of the resource, the most suitable locations for citing pads and land use planning and regulatory considerations.

10.15 Given the limited extent of exploration currently and absence of the production of shale gas in the UK at this point, there are no examples of Community Engagement Charters being negotiated between developers and local communities and other relevant stakeholders. However, there is the likelihood, as with onshore wind farms for example, that the approaches to establishing agreements and the use of the funds by communities will evolve over time as lessons are learnt and good practice emerges.

10.16 In addition to community charters, the UK Government announced in January 2014 that English local authorities would retain the business rates collected from shale gas sites. This does not currently apply to development which occurs in Wales.

Potential Impacts on Tourism Activity

10.17 This section considers the extent to which the localised impacts outlined above could result in adverse effects on tourism activity in areas local to development sites.

Evidence Base Relating to Tourism Impacts

10.18 As the unconventional gas sector is relatively new to the UK, the evidence base in relation to tourism effects is limited to a small number of ex-ante assessments. UK studies tend to focus on environmental impacts (such as visual, noise, traffic and air quality impacts) individually and there are none which consider the wider effect of these impacts on tourism activity. For example a comprehensive study carried out by the Department of Energy and Climate Change[1] draws upon ex-post evidence from overseas to assess environmental impacts but does not assess tourism impacts directly. Similarly, the Environment Agency assessment of infrastructure involved in Unconventional Gas Development[2] considers visual impacts but does not explore the effect on tourism.

10.19 Even assessments focused on individual developments (such as the Environmental Statement for exploration activity around Preston New Road in Lancashire[3]) tend to assess each impact type in isolation. The Preston New Road assessment looked at each of the types of localised impact outlined above but did not go on to explore potential wider effects on tourism activity.

10.20 Even from international sources, the evidence base around potential impacts on visitor perceptions, experiences or behaviour is limited. Most of the studies which have explored tourism impacts are from the US and while they are helpful, they do not provide a reliable evidence base to inform an assessment of the potential tourism effects in Wales (given that the tourism context and scale of development in the US differs substantially from that expected in Wales). However, while their

[1] Department of Energy and Climate Change (2011) Impacts of Shale Gas and Shale Oil Extraction on the Environment and on Human Health

[2] Ricardo-AEA (2014) Environment Agency, Unconventional Gas in England: Description of Infrastructure and Future Scenarios

[3] Cuadrilla Bowland Ltd (2014) Temporary Shale Gas Exploration, Preston New Road, Lancashire.

findings cannot be directly transferred to Wales, there are some useful insights from the international research. In particular related to:

- Potential temporary benefits for the tourism sector during the exploration phase: Cornell University prepared a report in 2011[4]which drew upon ex-ante and ex-post evidence to explore the potential impact of unconventional gas developments on tourism. The report concludes that there could be temporary benefits for local tourism business, through expenditure effects linked to the accommodation and hospitality requirements of a temporary workforce.
- Scope for longer-term negative effects in some instances: the analysis also suggests that individual sites are likely to have little impact on the tourism sector as a whole but widespread drilling could have a large cumulative effect on the long term growth of tourism through damaging the brand of the region where the activity is located especially if the if the area promotes itself on the basis of its high quality landscapes It is important to note that the scale and concentration of activity that this report considers is far greater than that which is likely to occur in Wales.
- Effects on tourist perceptions of an area: there is some additional research which suggests that unconventional gas exploration could have an adverse effect on the way that tourism destinations are perceived by visitors, and as such could discourage visits. A meta review of US peer-reviewed studies reaches the conclusion that whether fears of environmental contamination are realistic or not, there could be a permanent, negative impact on public perceptions of a rural area with a significant tourism sector[5]. While the physical effects of exploration and production are time limited and not always severe, there might be potential for the general sentiment of tourists to be affected, whether the impacts are actually significant or not.

10.21 The limited number of studies and the focus on the US which is likely to have a different development pattern and density to the UK, makes it difficult to draw robust conclusions about potential tourism impacts so it is helpful to look to other sources of evidence. The literature relating to the potential impact of wind farm developments on tourism activity can provide some insight here. Although wind farm developments differ substantially from unconventional gas developments, there are some parallels which make this evidence base particularly useful:

- *Visual impacts are a potential source of tourism impact for both wind farms and unconventional gas developments:* arguably, the visual impact of wind farm developments could be greater than for unconventional gas developments as they have more prominent visual features which persist for a longer period. It is however worth noting that wind farms can be viewed as both positive and negative additions to the landscape.
- *Noise impacts can cause localised problems for both types of development:* as for unconventional gas developments, noise associated with wind farms (albeit a different type and intensity of noise) is thought by some to be a potential source of adverse impacts on tourism activity.
- *Traffic disruption during construction activity for both development types can contribute to adverse effects on tourism*: as for UCG, traffic associated with wind farm construction can cause localised disruption and make tourism areas less easily accessible.

[4] Andrew Rumbach, Cornell University (2011) Natural Gas Drilling in the Marcellus Shale: Potential Impacts on the Tourism Economy of the Southern Tier.

[5] Jannette M. Barth (2013) The Economic Impact of Shale Gas Developments on State and Local Economies.

10.22 A comprehensive review of the literature relating to potential tourism effects of wind farm developments was carried out in 2013[6]. The findings of this review provide some useful insights to guide an assessment of the potential impact of unconventional gas developments on tourism activity. In particular:

- *There is substantial variability in the extent to which tourists alter their visiting behaviour in response to developments.* For wind farm developments, this partly reflects the subjectivity of visitors' assessment of their effect on the landscape but, more relevant to unconventional gas developments, this variability also reflects the range of reasons why tourists might visit a particular area, the complexity of their decision making processes and the likelihood that the relative importance of scenery, landscape and tranquillity will affect a decision to visit an area from one tourist to the next.
- *Although some tourists might view particular developments to be visually intrusive, this does not necessarily carry across into their visiting behaviour.* This is an important point: visual and noise impacts which are perceived negatively by visitors do not necessarily result in changed visiting behaviour. The actual propensity to change visiting behaviour is driven by a range of factors including the reason for their tourism visit, the activities tourists wish to engage in and the extent to which the development effects these.
- *Amongst the minority of tourists who might change their visiting behaviour as a result of a development, a sizeable proportion would still visit the region / wider area.* This means that the visits are not lost, but displaced to a different area. This conclusion could carry across to unconventional gas developments although this would not remove the possibility for localised effects.
- *There are factors relating to the characteristics of developments and the characteristics of tourism areas which influence tourist reactions.* This evidence could be helpful in predicting more localised impacts and highlighting the circumstances under which unconventional gas developments could result in negative effects. The literature relating to wind farms suggests that:
    - Smaller developments generate a less negative response from tourists
    - There is potential for greater impacts to occur where developments are sited in areas of high landscape value
    - The potential for developments to have a negative effect on tourism activity is greater where landscape or reality / tranquillity is dominant in an area's tourism offer
    - Areas where demand for tourism services (e.g. accommodation and leisure facilities etc) outstrips supply would be less sensitive to developments as pricing effects would be unlikely to kick in as replacement demand would take up capacity left by any visitors who were discouraged as a result of development.

10.23 The evidence base is not conclusive and further research is required to assess the extent to which these insights hold for unconventional gas developments. Although there are weaknesses in the evidence base, it is possible to draw a general conclusion that **local context and site specific factors are central in determining potential tourism impacts of unconventional gas developments**.

10.24 This means that it is not possible to assess potential tourism impacts fully without an understanding of the characteristics of particular developments and the locations in which they are planned. It is however possible to infer from the evidence base the type of tourism areas which might be more

[6] Welsh Government (2014) Study Into the Potential Economic Impact of Wind Farms and Associated Grid Infrastructure on the Welsh Tourism Sector

sensitive to development. The evidence suggests that the potential for negative effects is greatest in tourism areas where:

- High quality (and previously undeveloped) landscapes are a key and dominant feature of the visitor offer
- Peace and tranquillity (i.e. the absence of noise) is an important and dominant feature of the visitor offer
- The tourism offer or the visitor profile is less diverse and more focused on the nature of the natural environment.

Implications for Tourism Activity in Wales

10.25 The 14th Landward Licensing Round offers land in the following areas:

- North East Wales: licences extend into the eastern edge of Flintshire and encompass much of Wrexham and the northern tip of Powys
- South East Wales: licences in southern Wales stretch across from the South Eastern edge of Wales to Swansea (but exclude the Gower) and encompass parts of Eastern Carmarthenshire.

10.26 Although it is helpful in highlighting the broad tourism areas which might be affected, it does not provide sufficient insight into the precise locations of activity to allow a comprehensive assessment of potential effects. Potential impacts on tourism activity will be assessed as part of the planning process and any significant adverse effects would be identified.

10.27 The areas extend into, or are located close to, some of Wales's strategically important tourism assets including:

- Brecon Beacons National Park – this important tourism asset is adjacent to a large area of round 14 licenses which encompass the valleys and coastal parts of south east Wales.
- Wye Valley Area of Outstanding Natural Beauty - licenses within the Monmouthshire local authority area extend into this area.
- The Gower Peninsula - although the peninsula itself is not covered by the current licensing round, adjacent licenses encompass the Mumbles (an important gateway to the Peninsula and key tourism area in its own right).

10.28 Landscape and the natural environment is central to the tourism offer in these areas so we would expect them to be particularly sensitive to development. The landscape designations in these areas will ensure that developments do not take place within them, although the local planning process will need to assess the extent to which nearby developments are perceptible from them. The licensing areas also extend into tourism areas which might be viewed as less sensitive as part of a high level assessment. For example, the tourism offer in Neath Port Talbot is varied (encompassing active pursuits such as mountain biking and walking, heritage activities as well as traditional seaside tourism). While the area is not viewed as strategically important to Wales's overall tourism offer there are aspirations locally to grow the tourism sector and build upon key assets (such as the mountain biking offer in Afan Forest Park). Landscape and the natural environment are important to some aspects of Neath Port Talbot's tourism offer but overall is not as critical as it is in more sensitive areas such as the Gower or Brecon Beacons National Park. While the area might be less sensitive as a whole, it is important to note that there may be particular parts of Neath Port Talbot where landscape and the natural environment are central to the offer and so, at a very local level, there could still be scope for unconventional gas developments to have some effect on the nature of the tourism offer and visiting behaviour.

10.29 This underlines the importance of a comprehensive tourism assessment as part of the local planning process. Potential tourism impacts of developments will need to be assessed on a case by case basis, considering the nature of tourism activities in close proximity to any developments and the extent to which any visual, noise, traffic and air quality impacts could detract from the offer and deter visitors.

Summary

10.30 The study also considered the range of socio-economic benefits and disbenefits that the development of unconventional oil and gas may have on the local communities which host these activities. These may include the benefits associated with the access to employment and related training, increased demand for local goods and services and community benefits packages (through the voluntary scheme proposed by UKOOG), as well a range of potential disbenefits associated with the disruption to local communities due to protests, loss of amenity and environmental quality (associated with visual, noise and air quality impacts) and pressure on local social and community infrastructure (through the demands of and use by mobile workers).

10.31 Although again subject to a great deal of uncertainty associated with the scale, location and timing of development activity, as well as the potential for these impacts not yet being tested thoroughly within the UK, the current evidence tentatively suggests:

- The potential to access employment opportunities on or close to site (with the developer or first tier suppliers) by local residents may be limited, although there will be a range of economic activity and hence jobs supported locally associated with the supply of a range of goods and services (eg in retail, hospitality, etc). Nevertheless, these may still be important benefits for communities which are affected by high unemployment.
- The community benefit payments could represent significant additional income for local communities although the potential to secure long term benefit for these communities depends on the scale of the payments and the mechanisms put in place for allocating and spending this income.
- Many of the disbenefits associated with development that local communities experience are likely to be concentrated during the exploratory and preparation period and hence short term in their nature. We would expect these disbenefits, where they are significant in EIA terms, to be mitigated through the planning and regularity process.

Appendix A - Economic Modelling Framework

Objectives and Caveats

A.1 This section describes the methodology used to generate our estimates of the potential regional economic impact of unconventional gas exploitation in Wales. Here we seek to estimate the (current) value of potential investment in terms of the gross value added and employment (full time equivalent jobs) for the Welsh economy. Whilst the method and outputs largely mirror work undertaken for other energy sectors in Wales (for example onshore wind and marine renewables) there are a number of important differences and restrictions to the current analysis.

A.2 Firstly, previous energy studies majored on the construction of facilities, or development of sectors in the field of electricity generation. Clearly the current study examines mineral extraction activities, albeit for a fuel that would be used in part for electricity generation. Whilst this distinction is mostly irrelevant in the assessment of regional economic impact, it does mean that a number of metrics reported in previous energy studies – chiefly employment per MWe installed – are not applicable and hence not reported.

A.3 Secondly we face serious issues around data quality and hence scenarios – Data on commercial extraction of shale gas and coal-bed methane in Europe are scarce, for the reason that very little has hitherto occurred. Even in countries where there is a proven resource, and a reasonably positive government attitude (e.g. Poland) progress has been slow, and characterised by an unwillingness of international capital to invest[124]. Europe is in a 'chicken-and-egg' situation, where tens to hundreds of test wells are required to judge the possibility of play-viability, but where regulatory, public-opinion and other barriers combine with the low price of gas (in part due to US shale supplies) to dissuade such investment[125]. The paucity of real data on commercial UCG extraction, per well and in aggregate total, means that the costs, scenarios and economic impact described in this report should be treated with great caution.

Outline Methodology

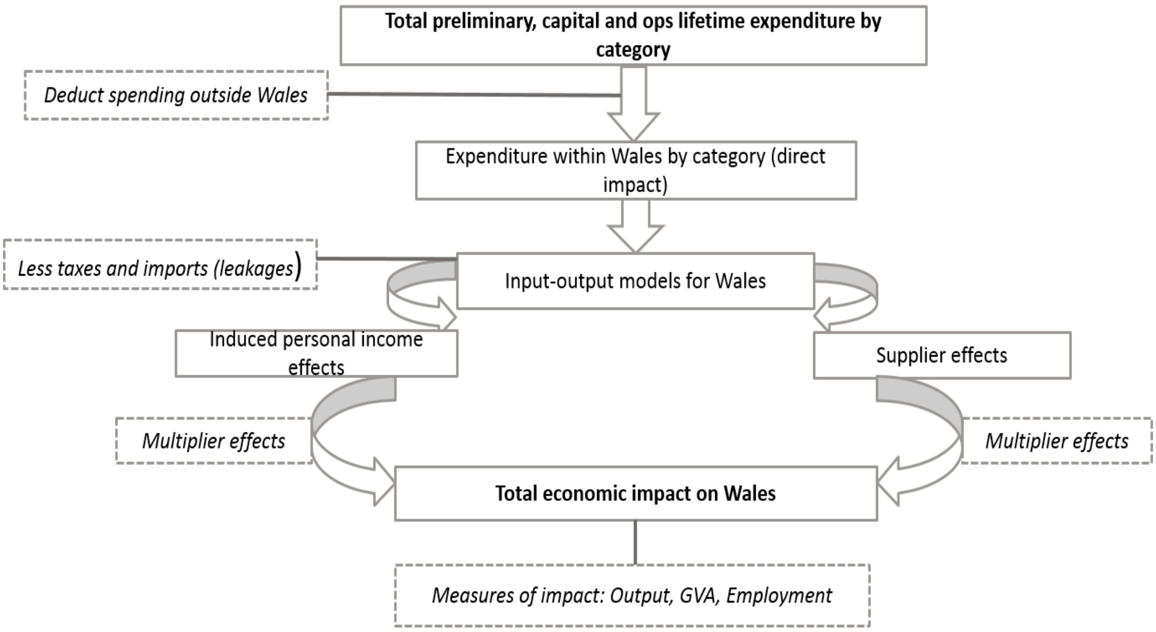
A.4 In this report we use the Input-Output (IO) Tables for Wales to estimate the gross value added (GVA) and full-time equivalent employment that might be generated in Wales, consequent the exploitation of unconventional gas reserves following three different scenarios. The IO Tables allow an assessment of the direct (on-site), indirect (supply chain) and induced (wage related) effects of new or potential economic activity (albeit here, as already noted, with significant caveats regarding data quality and scenario reliability).

A.5 Figure x.1 illustrates the conceptual model; new economic activity at shale extraction locations generates new economic activity in Wales, directly on site, and then as shale (or coal bed methane) extractors demand Welsh labour, goods and services in pursuit of gas extraction, with these supply chain impacts potentially extending for some rounds along the supply chain. Further economic activity is induced as workers in shale and supplying companies spend their wages, in part, in Wales.

[124] http://www.brookings.edu/research/opinions/2013/11/15-shale-gas-oil-boom-europe-boersma and see section x.x for detailed discussion

[125] http://www.lngworldnews.com/wood-mackenzie-cautions-commercial-viability-of-uk-shale-gas-remains-to-be-proven/

Figure A.1 The Modelling Approach



Source: WERU, Cardiff University

A.6 In parallel with other energy reports earlier published, there is an issue with the identification of direct and indirect impacts (labour and GVA) that is necessary to estimate economic multipliers. We would expect, for unconventional gas, the scale of *on-site* subcontracting to be both extensive and currently un-knowable. The extent of such activity fundamentally drives the scale of the economic multiplier (which is total divided by direct impact), albeit with no impact on the overall level of activity generated in Wales. In common with earlier publications, we therefore do not report direct and indirect impacts separately in this study (or any economic multipliers).

A.7 Whilst Input-Output analysis has a longstanding history in Wales, using regionally bespoke tools and data, it faces a number of inherent limitations and simplifications. For example, it is very difficult to account for economies of scale, or changes in technological approach or the geographies of supply chains (although our scenario analysis is intended to address this latter concern)[126]. For the as-yet regionally untested UCG activities the methodological constraints are more challenging yet. For example, the likely industrial geography and evolution of shale extraction in the UK (or Europe) is unknown. In the US, the industry is characterised by a far higher level of peripatetic capital than is the norm for other industries, driven by the relatively short extractive life of shale (gas and oil) wells, and the need to constantly drill in new locations to maintain production. Our attitude to the 'embeddedness' of capital in Wales will drive modelling assumptions and hence levels of reported economic impact. Additionally, US tight production is characterised by the convergence at well-heads of multiple companies with experience in onshore oil and gas combining savvy and machinery to undertake extraction and distribution operations. Given the severe lack of onshore oil and gas expertise, infrastructure and relevant tooling in Europe the mode of operation (and hence modelled production function) here is an open question.

A.8 The above issues notwithstanding, IO analysis is the most appropriate and locally-oriented methodology available to study the positive economic impacts of potential UCG extraction in Wales. Given the nature of available data (see following) and the uncertainties around potential

[126] For far greater detail see Miller R, and Blair P (2009) *Input-Output: Foundations and Extensions 2nd ed.* (Cambridge University Press, Cambridge)

scale of operations, we seek to establish the economic impact per lateral bore, with this then grossed to (assumed) numbers of wells and pads in our relative scenarios.

A.9 It should be noted that this section of the report deals only with the positive economic impact associated with UCG extraction. It makes no comment on the likelihood or *viability* of such investments given wider economic, energy cost, environmental and social contexts. These issues are addressed qualitatively in other sections of the report.

Data Sources

A.10 To inform our economic impact assessment, we require estimates of capital and operational spending associated with commercial shale extraction in Wales. To ensure consistency with other studies we require as full an analysis as possible, encompassing site survey, access costs, preparation and drilling, and operational expenditure. Here, unlike for some much longer-lived investments[127], we will also seek to include decommissioning costs (which will somewhat advantage shale estimates compared to other developments). Relevant expenditures must then be categorised according to the 88 sectors in the Welsh Input-Output Tables, with an assumption made in each case around how much of that expenditure is in Wales as opposed to with companies elsewhere (either under current or improved local supply conditions).

A.11 As noted earlier, the data available to estimate the likely pattern of expenditures in UK commercial shale exploitation are very limited (and all of course *ex ante* estimates) – and of course data on the level of regional sourcing are wholly absent. A number of studies exist and have been referenced for this report (see Figure x.2) but it should be noted that none of these really comprise the high quality, transparent and neutral analyses one would prefer. Methodology and data sources are typically obscure, coverage and classifications vary significantly, and in some cases sponsoring bodies have a financial interest in, or declared preference for, shale development in the UK.

A.12 Meanwhile there are a small number of US studies based on actual commercial exploitation, in the Magellan shales and in the lower-48 states overall (for shale gas and tight oil). These studies use a similar IO approach to our own study and hence, usefully, present estimates of spending according to specific and detailed industrial classification; and for exploration, drilling and operations separately. There is a significant caveat here however, in that we do not know what the production of shale 'look like' economically in Europe, but we do know it will *not* look like the USA – due to geological, infrastructural and other factors. However, in the absence of Europe-specific data, US evidence on the different vectors of spend associated with exploitation will be useful, even if overall cost per MMTU in the UK will be likely considerably higher.

A.13 Our analysis amalgamates US data on spend vectors with UK estimates on costs (with some of this by broad activity) to produce an estimate of the cost per lateral bore for UK shale gas and coal bed methane, with this disaggregated by 88 industrial sectors. Given uncertainty over the evolution of shale exploitation, we estimate total costs for the lifetime of the well, presented in £2014.

A.14 We then use our extensive knowledge of relevant supply side activities in Wales to estimate the level of local sourcing associated with each input, and in the supply of labour (with these varying in our scenarios). This per-bore estimate of new economic activity is then used as an input to the IO Tables for Wales to estimate the direct/indirect and induced levels of gross value added and

[127] Such as the 100+year Swansea Bay Tidal Lagoon; WERU (2013) Turning Tide: the economic significance of the Tidal Lagoon, Swansea Bay http://tidallagoon.opendebate.co.uk/files/TidalLagoon/DCO_Application/6.4_22.1.PDF

employment, with these impacts then aggregated to produce our scenario estimates based on numbers of bores, wells and pads.

Appendix B - Skills Matrices

Table B.1 Pre-Drilling Phase Occupational Matrix

Natural Gas Extraction
Education / Job Matrix Pre-Drilling Phase

	Associated Jobs	Secondary/ Career and Technical Centres	Work Experience/ Certification	Post-Secondary/ Higher Education
Geological Studies	Geologists & Geophysicists			x
	Hydro Geologist			x
	Petroleum Engineers			x
	Petroleum Chemists			x
	Cartographer			x
Seismic	GIS Technicians		x	x
	Project Management		x	x
	CDL Drivers		x	x
	Helicopter Pilot/Crew	x	x	
	Seismic Crew		x	x
Public Land Only	Water Management			x
	Forester	x	x	x
	Archaeology			x
	Biologist			x
Mineral Rights	Land men-for drilling/leasing		x	
	Lawyers			x
	Para-legal1	x	x	x
	Title-Abstract	x	x	x
Permitting Process	Lease Acquisition		x	x
	Lease Admin		x	
	Environmental Technicians		x	x
	Lawyers		x	
	Permitting Tech1			x
Staking the Well	Roadman		x	
	Surveyors		x	x
	Civil Engineering Tech			x
	Civil Engineer			x
	Leasing Agents (Right-of-Way)		x	
	Land Clearing		x	x
	Heavy Equipment Operators	x	x	x
	Heavy Equipment Maint Tech		x	x
	Logging		x	
Water Mgmt	Water transfer/Driver CDL		x	
	Hydrologist stream monitor			x

Source: Marcellus Shale Education & Training Center, Workforce Needs Assessment, 2009

Table B.2 Drilling Phase Occupational Matrix

Natural Gas Extraction
Education / Job Matrix Drilling Phase

	Associated Jobs	Secondary/ Career and Technical Centres	Work Experience/ Certification	Post-Secondary/ Higher Education
Pipeline Construction	Construction Managers		x	x
	Foreman	x	x	x
	Superintendent		x	x
	Petroleum Engineers		x	x
	Pipe Fitters		x	x
	Welders		x	x
	Welder Helpers	x	x	
	Well Inspectors		x	x
	Heavy Equipment Operators		x	x
	X-Ray		x	
	X-Ray Tech		x	x
	General Labour	x		
	Boreing Crew	x	x	x
	Environmental Tech-Monitoring Reclamation		x	x
	Operational Landmen	x	x	
	Surveyors			x
	Civil Engineering			x
Compressor Construction	Logging		x	
	Construction Managers		x	x
	Welders		x	
	Werlders Helpers	x	x	
	X-Ray		x	
	X-Ray Tech		x	x
	General Labour	x	x	
	Land Clearing	x	x	
	Foreman		x	x
	Pipeline Inspection		x	x
Drilling	Company Man/Geologist		x	x
	Drilling Engineer		x	x
	Drilling Superintendent		x	x
	Tool Pushers		x	
	Roughnecks	x	x	
	Roustabouts		x	
	Diesel Technicians		x	x
	Rig Mover		x	
	Heavy Equipment Operators	x	x	x
	CDL Drivers		x	
	Mudmen	x	x	x
	Welders		x	x
	CDL Drivers		x	
	Electricians		x	x

	Cement Pumpers		x	
	Well Logging			x
	CDL Drivers		x	
	Directional Drilling		x	x
	Finishing Rig		x	
Fracking and Completion	Supervisors		x	x
	Safety		x	x
	Foremen		x	x
	Site Management		x	x
	Petroleum Engineers			x
	Frac Crew	x	x	
	Heavy Equipment Operators		x	x
	Heavy Equipment Maint Tech		x	x
	CDL Drivers	x	x	
	Roustabouts		x	
	Heavy Equipment Operations		x	x
	Crane Operations		x	x
	Environmental Inspection		x	x
	Flowback Analyser		x	
Water Management	CDL Driver/Water Haulers	x	x	
	Hydrologist/water supervisor			x
	Completion-xaferers		x	
	Water Testing/Quality		x	x
	Flowback		x	
Overall	Road Crews	x	x	
	Heavy Equipment	x	x	x
	CDL		x	
	Local Liaison		x	
	Safety/OSHA			x
	First Aid		x	
	Security		x	
	Calibration Technician		x	x
	Office Management		x	x
	Clerks/Data Entry/Reception		x	x
	Financial/Business Management			x
	Accountants			x
	Office Support - admin assist.	x		
	IT/Computer	x		x
	Purchasing		x	x

Source: Marcellus Shale Education & Training Center, Workforce Needs Assessment, 2009

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