European Commission

Technical Support for the Risk Management of Unconventional Hydrocarbon Extraction

Final Report

Europe Direct is a service to help you find answers to your questions about the European Union.

Freephone number (*):

00 800 6 7 8 9 10 11

(*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

LEGAL NOTICE

This document has been prepared for the European Commission however it reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

More information on the European Union is available on the Internet (http://www.europa.eu).

Luxembourg: Publications Office of the European Union, 2016

ISBN 978-92-79-57947-9
doi:10.2779/001875

European Commission DG Environment

Technical Support for the Risk Management of Unconventional Hydrocarbon Extraction

Final Report

Amec Foster Wheeler Environment & Infrastructure UK Limited

August 2015

Disclaimer

This Final Report has been prepared by consultants Amec Foster Wheeler Environment & Infrastucture UK Ltd. The views expressed herein are those of the consultants alone and do not represent the official views of the Commission.

Copyright and Non-Disclosure Notice

Third-Party Disclaimer

Any disclosure of this report to a third party is subject to this disclaimer. The report was prepared by Amec Foster Wheeler at the instruction of, and for use by, our client named on the front of the report. It does not in any way constitute advice to any third party who is able to access it by any means. Amec Foster Wheeler excludes to the fullest extent lawfully permitted all liability whatsoever for any loss or damage howsoever arising from reliance on the contents of this report. We do not however exclude our liability (if any) for personal injury or death resulting from our negligence, for fraud or any other matter in relation to which we cannot legally exclude liability.

Document Revisions (

No.	Details	Date
01	Interim Report	29th April 2014
02	Interim Report	5th September 2014
03	Draft Final Report	6th February 2015
04	Final Report	22nd July 2015
05	Final Report	17th August 2015

Report for

Unit F1, Resource Efficiency and Economic Analysis, DG Environment
European Commission
B-1049 Brussels
Belgium

Main Contributors

Caspar Corden (Amec Foster Wheeler)
Ben Fretwell (Amec Foster Wheeler)
Daren Luscombe (Amec Foster Wheeler)
Rob Whiting (Amec Foster Wheeler)

Issued by

....

Daren Luscombe

Approved by

....

Caspar Corden

Amec Foster Wheeler Environment & Infrastructure UK Limited

Ground Floor, Redcliff Quay, 120 Redcliff Street, Bristol, BS1 6HU
Tel +44 (0) 117 317 8950

Doc Reg No.

h:\projects\35229 ec risk man of unconventional hydrocarbons\d data\reports\final\35229 final (master) 20150817.docx

European Commission DG Environment

Technical Support for the Risk Management of Unconventional Hydrocarbon Extraction

Final Report

Amec Foster Wheeler Environment & Infrastructure UK Limited

August 2015

Management Systems

This document has been produced by Amec Foster Wheeler Environment & Infrastructure UK Limited in full compliance with the management systems, which have been certified to ISO 9001, ISO 14001 and OHSAS 18001 by LRQA.

Executive Summary

Purpose of this Report

This is the Final Report for the project 'Technical Support for the Risk Management of Unconventional Hydrocarbon Extraction', contract 070251/2014/674828/SER/ENV/F.1. The report presents an overview of the main unconventional fossil fuels (UFF) other than shale gas ('other UFF') that require hydraulic fracturing to enable hydrocarbon extraction, a comparison of the risks associated with other UFF and shale gas, consideration of the adequacy of technical and policy measures to mitigate environmental risks that were developed in previous work that focussed on shale gas for the management of risks arising from extraction of other UFF, and a description of selected policy options available to implement such measures, should the Commission decide that further action at EU level is needed. This report should be read in conjunction with the study report 'Technical Support for Assessing the Need for a Risk Management Framework for Unconventional Gas Extraction', contract 070307/2012/630420/SER/ENV.F.1[1].

Context

In January 2014, the Commission published its Communication and Recommendation on the exploration and production of hydrocarbons (such as shale gas) using high volume hydraulic fracturing in the EU[2]. In support of the Communication and Recommendation, Amec Foster Wheeler Environment & Infrastructure UK Ltd[3] undertook the study 'Technical support for assessing the need for a risk management framework for unconventional gas extraction'. Whilst the study focussed on shale gas with consideration of the implications and scope of potential policy proposals, there was a need to gather information regarding other UFF.

Shale gas is the UFF resource with the greatest potential recoverable resources in the EU; consequently work carried out to date in studies for the Commission has focused on shale gas. However, development of UFF other than shale gas is also taking place or is planned to take place in the EU, which requires further examination. The analysis in this study builds on the environmental assessment of shale gas carried out under previous work and widens the scope of the assessment to other UFF requiring hydraulic fracturing to initiate production (e.g. tight gas, tight oil, and coalbed methane (CBM)[4]). Other UFF present many of the same risks as shale gas; however, there

[1] Available at http://ec.europa.eu/environment/integration/energy/unconventional_en.htm

[2] Available at http://ec.europa.eu/environment/integration/energy/unconventional_en.htm

[3] Formerly AMEC Environment & Infrastructure UK Ltd

[4] CBM is extracted from virgin coal bed seams that have not been mined in contrast to coal mine and abandoned coal mine methane. Note that CBM may not require hydraulic fracturing to enable successful production. In the course of this study CBM operations in Europe where hydraulic fracturing has been used or is planned has not been identified. In Australia, where CBM resources are developed, to date less than 5% of CBM wells have been fractured, and this figure is unlikely to exceed 10% (New South Wales Government (2014)). USEPA (2004) indicates that hydraulic fracturing occurs in most CBM basins studied but does not indicate the proportion of wells requiring fracturing.

are differences between shale gas and other UFF such as techniques used, potential scale, types of geology and the depth of the target formations.

Objective, Scope and Boundary of the Study

The objective of this study is to build on the study 'Technical support for assessing the need for a risk management framework for unconventional gas extraction' and to provide support for the preparation of possible Commission initiatives on managing risks and potential impacts of other UFF extraction in Europe. The scope and boundary of the study can be summarised[5] as:

- Categorisation of unconventional fossil fuels;
- Comparison of risks and impacts of other UFF with each other and with shale gas;
- Development of measures to address any additional risks of UFF; and
- Assessment of possible policy options.

The scope of work does not include offshore UFF which is the subject of a separate Commission study.

This study has the following limitations:

- It should be borne in mind that there is limited extraction of other UFF involving the use of hydraulic fracturing in the EU so current work has had to take into account limited existing and potential future developments. The focus of the study is other UFF that uses hydraulic fracturing beyond shale gas.
- The focus of the study was on water-based fracturing. Non-water-based and new technologies would require a separate assessment of risks and technical measures if these were to be considered as part of a risk management framework.
- The influence of fluctuations in oil and gas prices (either up or down) was not assessed in terms of the effect this may have on measures that may be required. However, an indication of the likely impact of recent oil and gas price fluctuations is commented on.
- It should be noted that the cost estimates exclusively address preventive measures and do not include costs for remediation of accidental events.
- Estimates of affordability are highly dependent on a number of assumptions, including estimates of gas production volumes per well and assumed productive lifetime over which those volumes are realised, which will vary on a case by case basis.

[5] For the full scope refer to Section 1.4.

- Compliance costs and affordability estimates are based on best estimates for measure costs using single point values for option cost calculation. Costs may vary and there are uncertainties regarding costs across the large number of measures.

Conclusions

Differentiating Conventional Fossil Fuels and Unconventional Fossil Fuels

A universally recognised distinction between conventional fossil fuels (CFF) and UFF is not available. What is considered to be UFF may vary over time depending on various aspects (e.g. resource characteristics, technologies, scale, frequency and duration of production from the resource). The term 'unconventional' may be used to identify the use of previously rarely deployed techniques; however, such techniques may also be applied to CFF resources and so may no longer represent 'unconventional' techniques over time. An alternative definition refers to hydrocarbons present in the source rock in which the resource was originally formed. Such a definition includes shale gas and CBM but excludes tight oil and tight gas where hydrocarbons have migrated from a source rock to a reservoir.

A number of potential criteria are possible to differentiate between CFF and UFF. Firstly, the permeability of the reservoir rock may be considered. Shale gas, tight oil and tight gas are found in formations with lower permeability than CFF. However, the permeability of CBM is more variable and therefore cannot be readily distinguished from CFF on this basis. Secondly, the geological environment in which CFF and UFF are found may be used to differentiate as CFF are typically found in discrete accumulations (e.g. where a cap rock overlies and contains a reservoir) whereas UFF may be found in much more extensive bodies with more gradational boundaries. Thirdly, the techniques used to exploit CFF versus UFF and in particular the scale of drilling are different, with the extensive use of horizontal wells, and stimulation being required at the production stage for UFF. Fourthly, shale gas, tight gas and tight oil resources may be grouped as they share characteristics including depth, scale of operations at a well pad, the use of multi-well pads (and associated land take) and a requirement for the use of hydraulic fracturing to enable production. CBM resources form a separate group due to the shallower depth, reduced scale of operations, the use of hydraulic fracturing which is not always required and the smaller volume of fracturing fluid used for fracturing. In addition, CBM requires groundwater pumping whereas the other forms of UFF do not. Finally, whilst stimulation of reservoirs by hydraulic fracturing can be used in both CFF and UFF, there are differences in pressure and the volume of water used in the process.

Categorisation Options

Clear categorisation between CFF and UFF and also between different UFF may enable definition of those hydrocarbons falling under a given policy instrument. There is no single categorisation 'option' that captures all forms of UFF whilst avoiding capturing CFF; however, potential options for categorisation (see Section 2.2.5 for further detail and comment on the suitability of options) could be based on the following (or combinations thereof):

- Permeability of the reservoir formation.

- Volume of water used in hydraulic fracturing (for shale gas, tight oil and tight gas).
- Pressure applied during hydraulic fracturing.
- Depth, due to differences in risks presented by shallower operations (proximity to aquifers above wells) and deeper operations (greater pressures required for fracturing and the associated well integrity requirements).
- Depth for CBM, as such operations are more likely to be near aquifers used for drinking water or contributing to surface water flow.
- Volume of pumped groundwater for CBM.

Comparison of Risks and Impacts

Differences in the risk and impacts compared to shale gas were predominantly identified in the hydraulic fracturing, well completion and production stages, with CBM being more markedly different than the other UFF types. For tight gas and tight oil, risks and impacts linked to water resource depletion are potentially less significant than for shale gas because less water is typically required for the fracturing process.

For CBM, risks and impacts relating to traffic and air pollution during site identification and preparation, and the well design drilling, casing and cementing stage could potentially have lower risks due to the smaller scale and duration of operations and shallower well depths and distances resulting in shorter drilling times. However, for CBM, the hydraulic fracturing stage risks and impacts associated with groundwater contamination are potentially more significant compared to shale gas due to the comparatively shallower depth of the target formation compared to shale gas. CBM also requires pumping of groundwater at the production stage. The abstraction of groundwater presents a risk to water resources in overlying or lateral formations where a hydrogeological connection exists. The traffic burden (linked to transportation of produced water) and associated risks and impacts for CBM may potentially be more significant compared to shale gas.

Additional risks identified for CBM compared to shale gas were identified including a risk of surface water contamination from greater quantities of actively pumped produced water at the surface which must be managed and treated to the standard required by permits[6]. Also, risks of increased water resource depletion from groundwater supplies being drawn down towards the target formation and the potential for groundwater contamination due to the need for groundwater pumping and associated potential impacts on groundwater resources and quality are possible for CBM.

---

[6] Produced water has variable quality (e.g. USEPA (2013) and Umweltbundesamt (2013)) indicate a range from 7 to 128,000 mg/l total dissolved solids in produced water from CBM formations.

Policy Options Assessment

The costs and benefits of four policy options were assessed. The options were based on those set out in Section 4 of AMEC (2014). The four options were:

- Option A: to take forward guidance and a recommendation under existing legislation, voluntary industry agreement and best practice;
- Option B: to amend several existing EU laws and accompany this with guidance;
- Option C: to adopt a new dedicated legal instrument in the form of a directive (setting overall goals/principles) and accompany this with guidance; and
- Option D: to adopt a new dedicated legal instrument in the form of a regulation, to set specific detailed obligations and accompany this with guidance.

It should be noted that since the AMEC (2014) work was undertaken, the Commission adopted Recommendation 2014/70/EU in January 2014. The Recommendation is one part of Option A but it is not the full Option A.

Section 5.4 presents details of the costs of the policy options for other UFF. Compared to the option costs for shale gas, annualised costs are lower for tight gas and tight oil due to the greater assumed well lifetime of 20 years compared to that assumed for shale gas of 10 years (for example the cost to operators of Option A[7] for tight gas and tight oil of up to approximately €1 million per pad compared up to approximately €1.5 million per pad for shale gas). For CBM, although the assumed well lifetime is seven years compared to ten for shale gas, a combination of fewer measures selected and a reduction of the capital cost associated with well safety due to shallower well depth (1,000 m vs. 3,000 m for shale gas) and well horizontal length (250 m vs. 1,350 m for shale gas) combined with fewer wells per pad (four per pad vs. eight per pad for shale gas) reduces costs per pad (e.g. the cost to operators of Option A for CBM is up to approximately €0.8 million per pad compared to up to approximately €1.5 million per pad for shale gas)[8].

Taking account of measures that are likely to be applied as normal practice by operators is important so as not to overstate potential compliance costs. The effect of factoring uptake of measures due to the application of normal practice is to reduce the estimated total compliance costs from pre-adjusted estimates. The total annualised compliance costs of the selected policy options per pad taking account of measures that are 'likely' to be applied and those that will 'possibly' be applied are presented in Section 5.4. The impact of taking account of such measures is to reduce costs, e.g. for Option A approximate costs reduce for tight gas and tight oil from up to €1 million per pad to up to €0.4 million per pad and for CBM from up to €0.8 million per pad to up to €0.6 million per pad).

[7] The cost of Option A will be determined by the level of ambition adopted and hence could incur no cost for operators and authorities if a low level of ambition is embraced.

[8] Note that CBM well lifetimes are reported to vary significantly. USEPA (2013) indicates 5-15 years, Amec Foster Wheeler experience in Australia indicates 2-5 years and personal communication with European Gas Ltd (2015) has suggested 15-25 years. Adjusting well lifetime for CBM from 7 to 15 years would result in total annualised compliance costs per pad of Option A of approximately up to €0.5m.

The estimated compliance costs as a percentage of expected revenues for tight gas are similar in magnitude to those calculated for shale gas. The percentage of expected revenues for CBM and tight oil are higher than for tight gas and shale gas. This is due to the assumed lifetime production volumes and associated revenues, and in addition for CBM, the smaller reduction in compliance costs when taking account of measures that may be applied already by operators (see Section 5.4.2 for further details on this point). However, for some CBM, longer well lifetimes and higher gas production rates have been reported than those assumed hence compliance costs as a percentage of expected revenues will be lower (see Section 5.5. for further detail on this point).

Administrative costs associated with the options for tight gas, tight oil and CBM will be analogous to those determined in AMEC (2014) as the general nature of the options remains consistent.

Contents

1. Introduction

1.1 Purpose of this Report

This is the Final Report for a project on 'Technical Support for the Risk Management of Unconventional Hydrocarbon Extraction', contract 070251/2014/674828/SER/ENV/F.1. The report presents the outcome of work that will provide an overview of the main unconventional fossil fuels other than shale gas ('other UFF') that require hydraulic fracturing to enable hydrocarbon extraction, a comparison of the risks associated with other UFF and shale gas, consideration of the adequacy of technical and policy measures to mitigate environmental risks that were developed in previous work that focussed on shale gas for the management of risks arising from extraction of other UFF and a description of selected policy options available to implement such measures, should the Commission decide that further action at EU level is needed.

1.2 Context

In January 2014, the Commission published its Communication and Recommendation on the exploration and production of hydrocarbons (such as shale gas) using high volume hydraulic fracturing in the EU[9]. In support of the Communication and Recommendation, Amec Foster Wheeler Environment & Infrastructure UK Ltd[10] undertook the study 'Technical support for assessing the need for a risk management framework for unconventional gas extraction', reference ENV.F.1/SER/2012/0033. Whilst the study focussed on shale gas with consideration of the implications and scope of potential policy proposals, there was a need gather information regarding other UFF.

Whilst past EU exploration and production of hydrocarbons including natural gas have focused mainly on conventional resources, technological advances, in particular in the United States and Canada, have opened the possibility of development of fossil fuels from UFF. Shale gas is the UFF resource with the greatest potential recoverable resources in the EU; consequently work carried out to date in studies for the Commission has focused on shale gas. However, development of UFF other than shale gas is also taking place or is planned to take place in the EU, which requires further examination.

The support provided under this contract provides an assessment of risks and potential impacts of the exploration and production of other UFF to enable identification of technical measures to address these risks and impacts. The analysis is based on the environmental assessment of shale gas carried out under previous work and widens the scope of the assessment to other UFF requiring hydraulic fracturing to initiate production (e.g. tight gas, tight oil, and coalbed methane (CBM)[11]).

---

[9] http://ec.europa.eu/environment/integration/energy/unconventional_en.htm

[10] Formerly AMEC Environment & Infrastructure UK Ltd

[11] CBM is extracted from virgin coal bed seams that have not been mined in contrast to coal mine and abandoned coal mine methane. Note that CBM may not require hydraulic fracturing to enable successful production. In the course of this study CBM operations in Europe where hydraulic fracturing has been used or is planned has not been identified. In Australia, where CBM resources are developed, to date less than 5% of CBM wells have been fractured, and this figure is unlikely to exceed 10% (New South Wales Government (2014)). USEPA (2004) indicates that hydraulic fracturing occurs in most CBM basins studied but does not indicate the proportion of wells requiring fracturing.

Other UFF present many of the same risks as shale gas. However, there are differences between shale gas and other UFF such as techniques used (e.g. fracturing parameters), potential scale, types of geology and the depth of the target formations. These factors may influence the risks presented and mitigation measures required. The following table summarises a selection of parameters for other UFF.

Table 1.1 Summary of a Selection of Other UFF Parameters

	Tight Gas	Tight Oil	CBM
What is it?	Gas trapped in low permeability sandstones and occasionally carbonates. Permeability may be <0.1 millidarcy.	Oil trapped in fine-grained sedimentary rock (e.g. siltstones, sandstones, carbonates or shale). Permeability may be <0.1 millidarcy.	Gas extracted from un-mined (virgin) or un-mineable coal seams. Permeability variable.
Key characteristics	Gas does not flow easily without stimulation. Formations can extend for hundreds of thousands of km^2 and tend to be located deep underground (e.g. 1,800 to 4,200m). Horizontal drilling and fracturing required. Fracturing may require a lower fluid injection volume than for shale gas. Flowback from hydraulic fracturing 17-35%. Chemical additives are likely to be required. The additives used and their volume will be formation specific (range 0.5-2.0%). Additives similar to shale gas. Vertical, horizontal and multi-lateral drilling used. Pressure at the reservoir during fracturing around 690 bar, but influenced by depth.	Oil does not flow easily without stimulation. Formations tend to be located deep underground (e.g. 1,200 to 3,600m). Horizontal drilling and fracturing is required. Similar, or smaller, volumes of fracture fluid may be used to that for shale gas. Flowback from hydraulic fracturing 10-60% which may contain heavy hydrocarbons. Similar technology used to that of shale gas and similar chemical components of fracturing fluids. Flowback recovery may be higher than that for shale gas (e.g. approximately 60% vs. 30% in shale gas). Pressure at the reservoir during fracturing around 552 bar but influenced by depth.	Depth of reserves can be shallower than other UFF (e.g. 500 to 1,500m). Technology depends on operator preferences and coal seam properties. Requires depressurisation (by dewatering) to enable gas extraction through desorption from the coal resulting in high wastewater volumes. The salinity of such pumped water may vary from 1-128,000 mg/l chloride. Typically, fracture fluid volumes and pressures used are lower than for shale gas. If hydraulic fracturing used, flowback between 61-82%. Fracturing is not always required to enable gas extraction. Vertical, horizontal and multi-lateral drilling used. Pressure at the reservoir during fracturing around 207 bar but influenced by depth.

Sources: selected data from Table 2.1 and Appendix A.

1.3 Objective

The objective of this study is to build on the contract 'Technical support for assessing the need for a risk management framework for unconventional gas extraction' and to provide support for the preparation of possible Commission initiatives on managing risks and potential impacts of other UFF extraction in Europe. To this end the study:

- Identifies and assesses relevant measures for managing the risks from UFF developments other than shale gas;
- Prepares extended support for a possible impact assessment on the need, and possible options for further action at EU level, should it be deemed necessary; and

- In collaboration with the Commission and in the context of a possible wider risk management framework, provides support for developing possible measures and elements of that framework.

1.4 Scope and Boundary of the Study

The overall scope and boundary of the study can be summarised as:

- Categorisation of unconventional fossil fuels:
  - Establish technical and/or geological criteria that distinguish UFF from CFF[12] for possible categorisation option/s;
  - Identify the risks and impacts of other UFF and compare to shale gas, and define groups of UFF with similar risks and impacts;
  - Assess the extent to which enhanced stimulation techniques with similar risks and impacts are used by the conventional oil and gas sector; and
  - Identify technical criteria to distinguish between exploration and production phases of UFF, if and where relevant.
- Comparison of risks and impacts:
  - Identify a suitable risk matrix for assessment of risks;
  - Compare the risk and impact profiles of each UFF group identified with the risks and impacts of shale gas activities.
- Development of measures:
  - Assess whether the measures already identified for shale gas are proportionate to the risk and impacts of each UFF group;
  - Propose measures to address additional risks identified for other UFF, if any.
- Assessment of policy options:
  - Development of cost scenarios for policy options including contextualisation of costs with average revenues of other UFF activities and, if feasible, monetised benefits from reduced impacts.

The scope of work did not include offshore UFF which is the subject of a separate Commission study. It is not the purpose of the study to decide upon the most appropriate framework for managing the environmental risks of other UFF. Instead, the aim has been to provide information and data that can be used by the Commission in assessing the need for and impacts of any possible policy option, should action at EU level be deemed necessary.

This study has the following limitations:

[12] Conventional fossil fuels.

- It should be borne in mind that there is limited extraction of other UFF involving the use of hydraulic fracturing in the EU so current work has had to take into account limited existing and potential future developments. The focus of the study is other UFF that uses hydraulic fracturing beyond shale gas.
- The focus of the study was on water-based fracturing. Non-water-based and new technologies would require a separate assessment of risks and technical measures if these were to be considered as part of a risk management framework.
- The influence of fluctuations in oil and gas prices (either up or down) is not assessed in terms of the effect this may have on measures that may be required. However, an indication of the likely impact of recent oil and gas price fluctuations is commented on.
- It should be noted that the cost estimates exclusively address preventive measures and do not include costs for remediation of accidental events.
- Estimates of affordability are highly dependent on a number of assumptions, including estimates of gas production volumes per well and assumed productive lifetime over which those volumes are realised which will vary on a case by case basis.
- Compliance costs and affordability estimates are based on best estimates for measure costs using single point values for option cost calculation. Costs may vary and there are uncertainties regarding costs across the large number of measures.

1.5 Summary of the Study Process

The study built on work carried out previously that focussed on shale gas. A stepwise process was followed entailing (i) categorisation of UFF, (ii) comparison of risks and impacts identified for shale gas with those of other UFF to enable assessment of whether the measures already identified for shale gas are proportionate to the risk and impacts of other UFF, (iii) development of further measures as necessary and then (iv) assessment of policy options selected by the Commission.

Any required Impact Assessment of the potential policy options is to be carried out by the Commission, taking into account not only the information gathered and analysed in this study, but also that of a number of other related studies.

1.6 Report Structure

The report is presented in the following sections:

- Categorisation of UFF: criteria that may be used for categorising UFF are presented, populated with data where possible, and options for categorisation are discussed;
- Comparison of risks and impacts: the approach to and results of comparison of risks of other UFF to shale gas is presented;
- Measures: a review of measures developed for shale gas is presented, together with an assessment of whether or not the measures are likely to be proportionate to the risks presented by other UFF;

- Policy options to deliver the measures: a description of policy options followed by an assessment of potential options considering specific combinations of measures as selected by the Commission; and
- Conclusions.

2. Categorisation of Unconventional Fossil Fuels

2.1 Introduction

The objective of this section is to discuss criteria that may be used to derive a technical definition of the types of UFF relevant to the EU (i.e. the types of UFF that might be developed in EU Member States). In addition, the risks and impacts of UFF are discussed with the aim of defining groups of UFF with similar risks and impacts profiles. Where relevant, distinctions are made between risks and impacts at the exploration and production phases. Consideration has been given to the extent to which stimulation techniques with similar risks and impacts to those used in UFF are used by the conventional (CFF) oil and gas sector. Furthermore, the stages of UFF development are described to permit potential distinction between the exploration phases and the production phase of all UFF where relevant.

2.2 Categorisation of CFF and UFF

2.2.1 Introduction

The oil and gas industry distinguishes between CFF and UFF resources. This distinction relates to the geological setting in which fossil fuel resources are located and not to the fossil fuel itself.

The United States Energy Information Administration (2013) considers UFF production to be an 'umbrella term for oil and natural gas that is produced by means that do not meet the criteria for conventional production'. It notes that what is considered to be UFF at any particular time is a complex interaction of resource characteristics, the exploration and production technology used, the economic environment, and the scale, frequency and duration of production from the resource. It also notes that these factors change over time and that perceptions differ among users of the terms CFF and UFF. A similar consideration of technical difficulty and cost is given in IEA (2012) definition, which states that 'unconventional gas refers to a part of the gas resource base that has traditionally been considered difficult or costly to produce'

The term 'unconventional' is typically used to identify the use of previously rarely used techniques such as horizontal drilling and high volume hydraulic fracturing to extract the resource. However, these techniques are now applied to many CFF resources and sufficiently frequently that they no longer represent unconventional techniques (DMEA, 2013). The use of high volume hydraulic fracturing has not been used to any great extent within Europe for hydrocarbon extraction. Lower volume hydraulic fracturing of some tight gas and conventional fields has been used in the southern part of the North Sea and in onshore in Germany, the Netherlands, Denmark and the UK (AEA, 2012).

2.2.2 General Categorisation

In general, CFF is defined as oil and gas that flows to a well bore in economic quantities without stimulation, i.e. oil and gas production by ‘conventional’ means. Typically this means that oil and gas flow under pressure when a field is first penetrated but at later stages pumping may be used. However, increasingly stimulation and enhanced recovery techniques are used to increase production within CFF as the industry seeks to maximise the amount of oil and gas that can be extracted from a field. The consideration of economic quantities in the definition of CFF would mean that what is considered conventional will depend on the cost of extracting the oil and gas, which will vary in response to technical developments, field characteristics and externalities including oil and gas prices.

There is no universally recognised definition of the dividing line between CFF and UFF. A frequently-quoted definition was provided by US Department of Energy in the 1970s based on permeability. This defined UFF as oil and gas in rocks with a permeability of less than 0.1 mD (millidarcy). However, it is not clear that this definition is meaningful in the modern context. A qualitative definition is set out in DMEA (2013), which suggests that CFF is trapped in rock with a ‘high’ porosity and permeability whereas as UFF is still trapped in a source rock characterised by ‘low’ permeability. However, they note that whilst techniques such as horizontal drilling and hydraulic fracturing are used to release UFF, horizontal drilling and fracturing are also used for CFF, although the combination of horizontal drilling and high volume hydraulic fracturing has rarely been used in Europe to date (AEA, 2012).

An alternative definition is that UFF refers to resources that are found within the source rock in which it was originally formed (Umweltbundesamt, 2013). This definition includes shale gas and CBM but excludes tight oil and tight gas where hydrocarbons have migrated from a source rock to a reservoir. Lechtenbömer et al , 2011 maintain that there is a no sharp distinction between CFF and UFF when considering permeability and instead suggest that there is a continuum from CFF in highly productive fields characterised by high permeability, through less productive fields, then tight gas and finally to very low permeability shale gas. The continuum is illustrated as a resource triangle (Figure 2.1) for the permeability range of producing formations (Figure 2.2).

The German Society for Petroleum and Coal Science and Technology (DGMK) has defined tight gas reservoirs with an average effective permeability for gas below 0.6 mD (Hagemann et al 2012), which is also the permeability at which lower royalties are payable on extracted gas in Germany.

The United States Geological Survey (USGS) resource assessment of unconventional oil and gas set out in Schmoker (1999) prefers the term ‘continuous accumulations’ to define unconventional resources. It defines the term through 16 geological criteria[13] relating to:

- The size and areal extent of the deposit and the nature of its boundaries;
- The way that hydrocarbons are retained within the reservoir (absence of seals or traps);

[13] (1) is regional in extent, (2) can have diffuse boundaries, (3) has existing "fields" that commonly merge into a regional accumulation, (4) does not have an obvious seal or trap, (5) does not have a well-defined gas-water contact, (6) has hydrocarbons that are not held in place by hydrodynamics, (7) commonly is abnormally pressured, (8) has a large in-place resource number, but a very low recovery factor, (9) has geologic "sweet spots" of production, (10) typically has reservoirs with very low matrix permeabilities, (11) commonly has natural reservoir fracturing, (12) has reservoirs generally in close proximity to source rocks, (13) has little water production (except for coalbed methane), (14) has water commonly found updip from gas, (15) has few truly dry holes, and (16) has Estimated Ultimate Recovery (EUR) of wells that are generally lower than EURs from conventional gas accumulations

- Relationships to water-filled deposits;
- Reservoir permeability;
- The pressure regime;
- The recovery factor of the reservoir and the total recovery at individual wells.

However, the term and the criteria used to define it do not appear to have gained common acceptance. In 'Guidelines for application of the petroleum resources management system, 2011' a joint publication of the Society of Petroleum Engineers (SPE), American Association of Petroleum Geologists (AAPG), World Petroleum Council (WPC), Society of Petroleum Evaluation Engineers (SPEE) and Society of Exploration Geophysicists (SEG), UFF is defined as "*Unconventional resources exist in hydrocarbon accumulations that are pervasive throughout a large area and that are generally not significantly affected by hydrodynamic influences (also called "continuous-type deposi*ts"). Such accumulations require specialized extraction technology, and the raw production may require significant processing prior to sale. Set against conventional resources, which exist in discrete petroleum accumulations related to a localized geological structural feature and/or stratigraphic condition (typically with each accumulation)".

Criteria that might be used to distinguish between CFF and UFF are set out in Table 2.1. Information in Table 2.1 compares the characteristics of CFF and UFF for these criteria to identify possible means to distinguish between categories. The information is compiled from a variety of researched and referenced literature sources and aims to provide a summary of the general nature and scale of significant differences between CFF and the UFF, however, the information presented may not cover the diversity of all cases that may be encountered.

Table 2.1 Comparison of CFF and UFF Criteria

Criteria		CFF	UFF			
Main	**Secondary**		**Shale gas**	**Tight gas**	**Tight oil**	**CBM**
Gas and oil flow to a well without stimulation or enhanced recovery		Yes although some stimulation/enhanced recovery may be required to maximise recovery	No	No	No	No
Areal extent of a play		Oil and gas fields usually occur in defined structural or stratigraphic traps that cover less than the full area of the reservoir, formation or play. Typically small surface area in Europe e.g. Wytch Farm, UK has a mapped surface area of <100 km^2 (estimated from [W])	Can extend up to a large extent of the formation, which can be large e.g. 250,000 km^2 for the Marcellus Shale in the US. Many European prospects have areas >1,000 km^2 ([A])	Extensive in the US. Potentially large areas in Europe (Germany, Hungary) but limited information in public domain	Extensive in US Limited information on plays in Europe. Potential deposits in Europe (27 plays identified by IHS CERA, 2013)	Can extend over large area up to the full extent of the coal. Large areas of coal in Europe but limited information on CBM potential.
Recovery factor (% resource recovered)		High (40 to 80%) ([B]). Oil being at the low end and gas at the high end.	15 to 35% ([A])	10% ([B])	1 to 22% ([F]),	High (50 to 90% ([C,D;E])
Reservoir rock geology		Sandstones Carbonates	Shale	Sandstones Carbonates	Siltstones, sandstones carbonates or shale	Coal
Reservoir rock structure		Oil and gas found in traps created by geological structures (e.g. antiforms, faults, salt diapirs)	Occurrence not related to traps	Occurrence not always related to traps	Occurrence not always related to traps	Occurrence not related to traps
Reservoir rock permeability		Various definitions: - more than 0.1 mD - 'high' permeability	Various definitions: - less than 0.1 mD - 'low' permeability	Various definitions: - less than 0.1 mD - 'low' permeability	Various definitions: - less than 0.1 mD - 'low' permeability	Variable

Criteria		CFF	UFF			
Main	**Secondary**		**Shale gas**	**Tight gas**	**Tight oil**	**CBM**
Reservoir rock thickness		Highly variable as it depends on the nature of the trap	Highly variable (e.g. 6-610 m for US shales ([I]) up to 900 m in UK in deep basins ([O])	Highly variable	Highly variable	Typically thin (<10 m)
Depth		Highly variable but increasingly deep 1,800 to 5,500 m ([H])	Variable (e.g. 180 to 4,000 m for US shales ([I]) 1,800 to 4,200 m ([H])	Typically deep (e.g. 3,500 to 5,000 m in Cloppenberg Germany ([J]) 1,800 to 4,200 m ([H])	Typically deep (e.g. 600 to 2,900 m in Canada ([I]) 1,200 to 3,600 m ([H])	Typically shallow ~e.g. 800 m in Falkirk ([L]); 1,000 m in Munsterlander-Becker Region, Germany ([J]), 600 to 1100 ([K]), 500 to 1,500 m ([H])
Drilling methods			Drilling methods do not distinguish between CFF and UFF, i.e the same drilling rigs and drilling methods are used.			
Number and type of wells	No. of wells per field	Typically few wells used but number increased when enhanced recovery techniques used. (e.g. Schoonebeeke in the Netherlands required 73 new wells for steam injection ([U])) (E.g. Wytch Farm – Europe's largest onshore CFF oil field has approximately 100 wells at 13 sites including injection and recovery wells) ([V]).	Large numbers (e.g. 200 to 800 proposed for NW England ([M])	Large (e.g. 300 wells for tight gas in Germany 9 ([J])	Potentially large e.g. in Bakken of North Dakota between 122 and 189 drilling rigs were active (2010 to 2014) NDIC website access 02 June 2014	Current schemes in Europe are small e.g. 20 wells in Falkirk ([L]) but schemes in the US have a typical size of 70 wells and the number of wells per basin exceeds 1000 ([N])
	Use of horizontal wells	Not always used	Generally used	Generally used	Generally used	Commonly but not always used. Falkirk scheme proposes the use of horizontal wells ([L])
	Length of horizontal	Variable e.g. up to 4800m at Wytch Farm	900-3,000 m ([H])	30-5,750 m ([W])	800-4,500 m ([F, H])	300-1,200 m ([H])

Criteria		CFF	UFF			
Main	**Secondary**		**Shale gas**	**Tight gas**	**Tight oil**	**CBM**
	Multi-well pads	Variable use. May be used onshore to reduce footprint (e.g. Wytch Farm in the UK)	Typical in US. Multi-well pads planned for Europe ([J])	Typical in US ([J]). 1-14 wells per pad ([J, W])	Typical	Dependant on the technique and well configuration used to extract gas (e.g. 4 indicated ([K])
	Pad separation	Large to avoid interference	1 to 5 km	1 to 5 km	1 to 5 km	Close to create interference
	Well density	1 well per 10 km^2 ([V])	1 well per 1 km^2 ([V])	1 well per 1 km^2 ([V])	1 well per 1 km^2 ([V])	1 well per 0.16 to 0.32 km^2 ([C])
Stimulation by hydraulic fracturing	Hydraulic fracturing	May be used	Required	Required	Required	Not always used
	Volume of water used per well per fracture	0.0 to 700 m^3 ([H])	7,600 to 34,100 m^3 ([H])	100 to 12,000 m^3 ([w, x])	500 to 25,600 m^3 ([H, I])	0.0 to 4,700 m^3 ([H])
	Injection pressure at reservoir	Depends on pressure regime / depth 828 bar ([H])	Depends on pressure regime / depth 690 bar ([H])	Depends on pressure regime / depth 690 bar ([H])	Depends on pressure regime / depth 552 bar ([H])	Depends on pressure regime / depth 207 bar ([H])
	Use of additives[1]	Required	Required	Required	Required	Not always used
	Use of proppants	Not always required	Required	Required	Required	Not always used
	Flowback volume	30% ([H])	50% ([Y])	17%-35% ([H, Z])	10-60% ([H])	61-82% ([H, AA])
	Cavitation	No information	No information	No information	No information	Used to increase permeability of wells in thick coal seams

Criteria		CFF	UFF			
Main	**Secondary**		**Shale gas**	**Tight gas**	**Tight oil**	**CBM**
Enhanced recovery techniques used		Gas injection (carbon dioxide, natural gas). Natural gas used in Europe but not carbon dioxide ([T]). Carbon dioxide has been used extensively in the US due to availability of natural carbon dioxide. Water flooding (widely practised in Europe ([T]) Chemical flooding Heat (steam) injection (used at Schoonebeeke, NL ([U]). Use is highly variable –and increases with time ([G])	No evidence of use CO_2 injection at experimental stage ([B]). Use is variable and decreases with time and rate of gas production ([Q])	No evidence of use. Use is variable and decreases with time and rate of gas production ([B])	No evidence of use	Lowering of hydrostatic pressure required. Use is high and decreases with time ([C,G]) CO_2 injection (technology at early stage of development)
Wastewater – produced water	Presence of naturally occurring radioactive materials (NORM)	Presence is formation specific	NORM typically present	Presence is formation specific	Presence is formation specific	Presence is formation specific
	Salinity of water	1,000 to 400 000 mg/l salinity ([S])	5,000 to 200,000 ppm ([P, R, X])		211 to 107,000 mg/l as chloride ([I])	1 to 128,000 mg/l as chloride ([C, Z]),
	Disposal routes North America (NA)	Treatment and deep injection in NA (to enhance recovery). Treatment and discharge to coastal waters (e.g. North Sea)	Treatment and deep injection in NA. Treatment and discharge to inland waters in NA	Treatment and deep injection (e.g. Germany)		Treatment and deep injection in NA Treatment and discharge to coastal waters (e.g. proposed by Dart Energy, in UK) Treatment and discharge to inland waters

Notes:

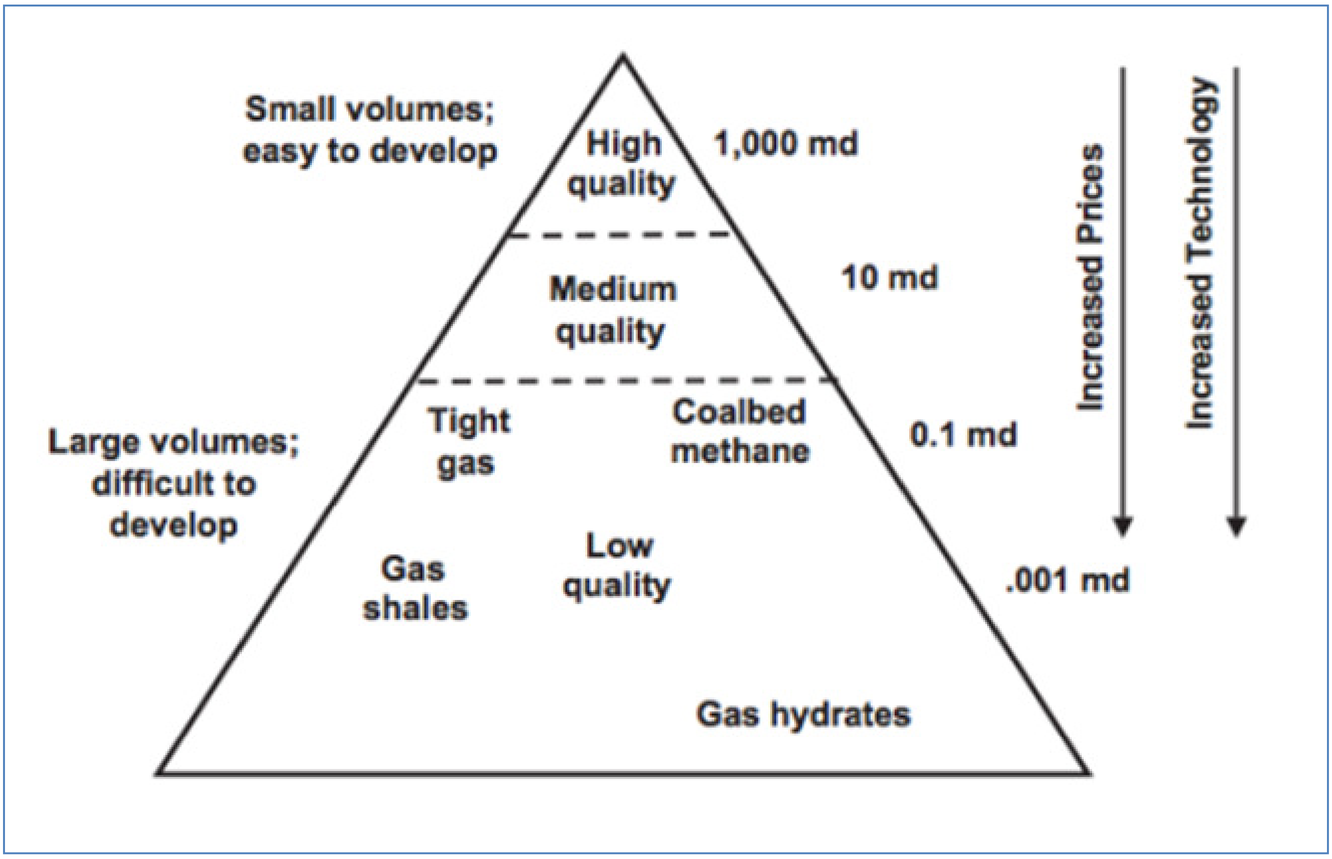
1 Additives are dependent on factors such as the formation, service company preference and prices.

References: [A] USEIA (2013); [B] MIT (2011); [C] Halliburton (2008); [D] Ryder Scott (2006);[E] Lea et al (2008); [F] CSUR undated; [G] USDOI (2011); [H] ICF (2013); [I] All Consulting (2012); [J] Ewen et al. (2012); [K] Environment Agency for England response illustrative play to questionnaire (2014a); [L] Dart Energy (2012); [M] Regeneris (2011); [N] USGS (undated); [O] DECC (2014); [P] Cuadrilla (http://www.cuadrillaresources.com/wp-content/uploads/2012/02/Summary-of-relevant-analytical-results2.pdf); [Q] UKWIR, 2014, [R] UB (2013); [S] USGS (2002); [T] Tzimas et al. (2005); [U] NAM (2010); [V] http://www.bdf.co.uk/projects_wytch_farm.php; [W] Landesamt für Bergbau, Energie und Geologie (2014), [X] AEA (2012), [Y] AMEC (2014), [Z] Umweltbundesamt (2013), [AA] USEPA (2014)

2.2.3 Geological and Spatial Categories

As indicated on the resource triangle (Figure 2.1), UFF reserves have a much larger volume (in terms of the volume of the reservoir) and they can cover much larger areas than CFF but have a lower amount of gas (or oil) (Holditch, 2006), or expressed another way UFF are less concentrated than CFF (IEA, 2012). For example, unconventional gas developments in the area of the Marcellus shales in the US (250,000 km^2) is 10 times larger than the largest CFF gas producing area in the US, the Hugoton Natural Gas Area in Kansas. (IEA, 2012). As a result, the technically recoverable reserves per unit area are lower for UFF than for CFF (IEA, 2012).

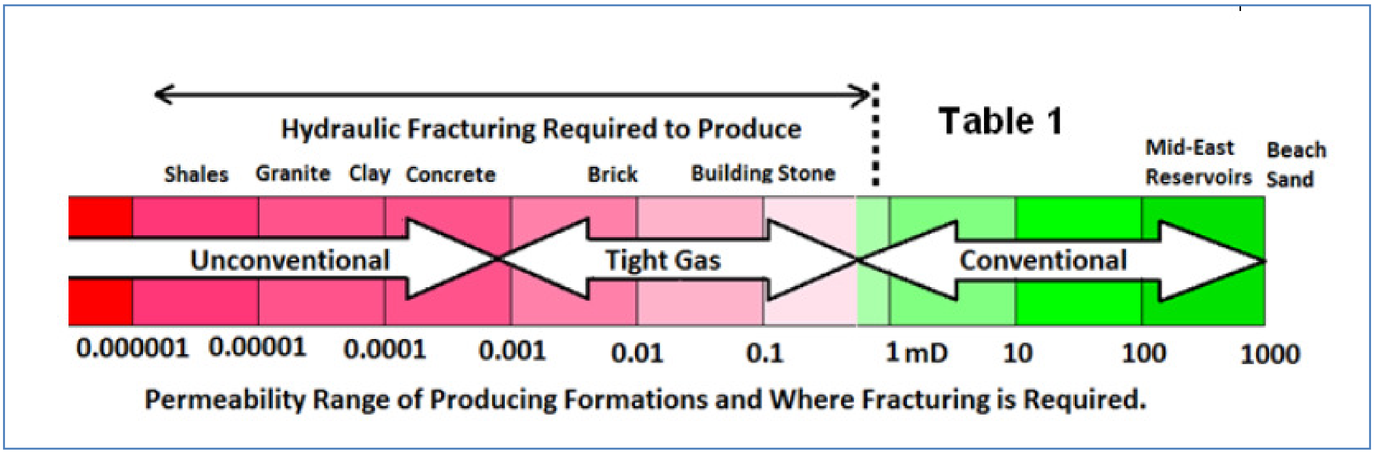
Figure 2.1 Resource Triangle for Gas Resources



Source: Holditch (2006).
md: millidarcy

It is evident from the information in Figure 2.1 and Figure 2.2 that a potentially significant differentiator between CFF and UFF is the permeability of the reservoir formation. Shale gas, tight oil and tight gas are found in formations with lower permeability than CFF. However, the permeability of CBM is more variable and therefore cannot be readily distinguished from CFF on this basis. Hydraulic fracturing of CBM is only likely to be required when coal has a low permeability (Halliburton, 2008). There is, however, a continuum of permeability from CFF to UFF) and, therefore, any permeability-based distinction requires an arbitrary line to be drawn on this continuum.

Figure 2.2 Permeability Scale for Distinguishing Between CFF and UFF



Source: King (2012)
mD: millidarcy

Another potential distinguishing factor is the geological environment in which CFF and UFF are found, as CFF are typically found in a trap, where a cap rock overlies, and contains, a reservoir. This means that CFF fields are likely to have well-defined dimensions. In contrast, UFF may be found in much more extensive bodies with more gradational boundaries from the play, into unproductive strata, where the edge is determined by economic as well as geological considerations.

The need for stimulation is a consequence of the low permeability of shale gas, tight gas and tight oil. For these forms of UFF stimulation is by hydraulic fracturing. For CBM enhanced recovery by depressurisation (groundwater[14] pumping) is required but stimulation by hydraulic fracturing may also be used albeit using relatively low volumes (0.0 to 4,700 m^3) of fluid, typically in vertical rather than horizontal wells (e.g. Halliburton, 2008).

A consequence of the low permeability of formations where other UFF are present is that individual wells have a limited zone of influence and, therefore, large numbers of wells (typically horizontal wells) are required to access the resource. In contrast, in more permeable CFF formations, hydrocarbons can flow to a well over larger distances and therefore fewer wells are required. Likewise, only vertical wells are typically needed to exploit CCF resources. However, even in CFF, large numbers of wells may be required towards the end of a field's life when enhanced recovery techniques such as water flooding may be used to extract remaining reserves, for example Schoonebeeke in the Netherlands has had 599 vertical wells drilled and a further 73 wells, including horizontal wells, are in the process of being drilled for steam injection to extract oil (NAM, 2010).

UFF may extend over larger areas than CFF. Areal extent will in general be greater for shale gas and CBM than tight gas and tight oil (i.e. the UFF sources where the source and reservoir rock are the same) because it is related to the lateral extent of the sedimentary formation rather than limited to the extent of a trap. Where sedimentary strata are relatively undisturbed, they can extend over many thousands of square kilometres, for example the Marcellus

[14] 'Groundwater' means all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil.

Shale in the Eastern United States of America extends over 250,000 km^2. Potential reserves in Europe can be of a similar scale (e.g. the Paris Basin extends over 170,000 km^2 of which approximately 46,000 km^2 is prospective for shale gas and in which tight oil reserves are also located (USEIA (2013). However, most European UFF are less extensive. They also tend to have more structural features, such as faults, than the plays exploited in North America. However, UFF may have limited areal extent, for instance the shale gas resources in the UK are mainly located in distinct fault-bounded basins that are of limited areal extent (DECC, 2010) rather than in laterally extensive sub-horizontal strata.

There are differences in the techniques used to exploit CFF and UFF and in particular the number of wells required, the extensive use of horizontal wells, and the extent of stimulation required at the production stage. However, there is also increased use of horizontal drilling and stimulation for CFF and in addition enhanced recovery techniques (water flooding, CO_2 injection, steam injection, chemical flooding etc.). However, the pressure required and the volume of CFF operations are generally less than those in UFF because the rock volume that is to be stimulated is smaller (DMEA, 2013)[15].

2.2.4 Stimulation and Recovery Techniques

Well stimulation is a general term describing a variety of operations performed on a well to improve productivity. It is generally divided into matrix treatments and hydraulic fracturing.

Matrix treatments are performed below the reservoir fracture pressure and generally are designed to restore the natural permeability of the reservoir following damage to the near-wellbore area (Schlumberger Oil Field Glossary - http://www.glossary.oilfield.slb.com). These treatments may be used on hydrocarbon wells for both CFF and UFF and are unlikely to be distinctive. They are not considered further.

Hydraulic fracturing involves the injection of a liquid under pressure via a well to induce fractures in rock. The liquid may contain particles, such as sand, that are carried into the fractures to maintain them open once the pressure has been released. These are termed proppants. The fractures allow gas or oil to flow out of the formation.

Where large volumes of fluid are used, then stimulation is sometimes referred to as high volume hydraulic fracturing. This is defined as operations using more than a particular volume of fluid (e.g. 380 m^3 (100,000 US gallons) of fluid (Michigan Department of Environmental Quality, 2011) per well or 1,140 m^3 (proposed by New York Department of Environmental Conservation, 2014)). The European Commission (2014) defined high volume hydraulic fracturing as 'injecting 1,000 m^3 or more of water per fracturing stage or 10,000 m^3 or more of water during the entire fracturing process into a well'.

Stimulation of reservoirs by hydraulic fracturing is used in both CFF and UFF. The main differences are the pressure and the volume of water used in the process, i.e. whether it is high volume or not; the number of stages of hydraulic fracturing (whether it is a multi-stage process or not); the volume and nature of additives and the volume and type of proppant used. In general, the volume of water used in shale gas is larger than is used in tight oil and

[15] Pressure is however reservoir, depth and formation dependent and could require high pressures.

particularly tight gas although wells in deep formations or with large horizontal lateral lengths can result in similar levels of water use to shale gas (ICF, 2013). Where hydraulic fracturing is used in CBM, then the volumes are typically small (ICF, 2013), the number of stages limited and the composition may vary between water only (as proposed by Dart in the UK) or with chemical additives as per shale gas fracturing. Furthermore, CBM does not always require the use of proppant to maintain fractures open as the goal of hydraulic fracturing is to develop and enhance the natural 'cleat' system within the coal.

CBM has used a stimulation technique known as cavitation to increase the size of the well at the point where it intersects coal seams in thick coal seams. Cavitation consists of a cyclic and repeated pressurising and de-pressurising of the wellbore, resulting in mechanical failure of the coal and the formation of a cavity in the coal that can be several metres in diameter (Loftin, 2009).

In addition to stimulation, the oil industry also uses enhanced recovery methods to increase production. In CFF, there are three phases of recovery: primary, secondary and tertiary (e.g. EPRI, 1999), as follows:

- Primary recovery occurs when there is sufficient pressure in the reservoir to force oil and gas to the surface, or only simple pumping arrangements are required;
- Secondary recovery methods involve the injection of fluids to increase reservoir pressure. Water injection is known as water flooding; and
- Tertiary recovery or enhanced oil recovery methods increase the mobility of the oil to increase extraction using heat (e.g. steam), carbon dioxide, chemical (chemical flooding) or microbial treatments.

The use of these techniques may lead to increased risks and impacts to the environment. The key additional risks and impacts for CFF, when compared to CFF without enhanced (secondary and tertiary) recovery are considered to be:

- Additional wells are required to provide injection points for steam or water: impacts related to land take at additional injection sites;
- Construction and drilling at additional injection sites: emissions to air from plant and related traffic;
- Water flooding: potential leaks and spills of saline produced water re-used for water flooding resulting in water pollution;
- Gas (carbon dioxide) injection: risks of fugitive emissions and leaks to atmosphere during the collection, transportation, injection and storage;
- Chemical flooding: leaks and spills of chemical additives (e.g. alkaline substances, surfactants, polymers) resulting in water pollution;
- Steam injection: emissions to air (carbon dioxide, NO_x) from heat / steam generation.

Some UFF makes use of some of the enhanced recovery techniques, notably:

- Lowering of hydrostatic pressure used in CBM to promote desorption of methane from coal (Halliburton, 2008); and
- Injection of CO_2 in CBM to reduce partial pressures of methane and to promote desorption of methane (USEPA, undated) from coal.

The above enhanced recovery techniques do not appear to have been used for shale gas, tight gas or tight oil but the use of carbon dioxide has been suggested as a possible means to enhance recovery in shale (MIT, 2011).

2.2.5 Summary of Categorisation Options

The term unconventional (fossil fuel) is frequently used in reference to shale gas, tight gas, tight oil and CBM to distinguish them from CFF. However, there is no widely accepted definition of this term and hence no unambiguous means of distinguishing all UFF from CFF on the basis of a single technical or geological criterion. Information in Table 2.1 presents a comparison of criteria that distinguish CFF and UFF. There are potentially, different categorisation options to group UFF and to then to distinguish these groups from CFF. A review of categorisation options suggests that shale gas, tight gas and tight oil can be grouped together as they share many characteristics including: depth; the scale of operations at a well pad; the use of multi-well pads / land take; and a requirement for the use of hydraulic fracturing to enable production; although the scale of the characteristics does vary across UFF. CBM forms a separate group and is distinct from shale gas, tight gas and tight oil due to the typically shallower depth of operations; the typically reduced scale of operations at well pads; the reservoir type (coal); production process (desorption); the use of hydraulic fracturing (not always being required to enable production) and the associated volume of fracturing fluid, which is smaller; and the use of chemical additives (not always used). In addition, CBM requires groundwater pumping to reduce pressure, whereas the other forms of UFF do not.

The main potential difference between shale gas, tight gas and tight oil compared to CFF is the use of greater volumes of hydraulic fracturing fluid in shale gas and in some tight gas and tight oil plays. Potentially, therefore, fracture fluid volume is a key distinguishing feature of UFF. However, the definition of what constitutes high volume hydraulic fracturing (HVHF) varies from 380 to 10,000 m^3 per well depending on the literature sources. The need for HVHF is partly a consequence of the lower permeability of UFF when compared to CFF and so permeability may also be a distinguishing feature. CBM is unlikely to use of HVHF at the higher end of the range (10,000 m^3 per well), but could potentially be captured under the lower limits of the range (380 m^3 per well), as could CFF if volumes at the higher end of the CFF range are required and the lower limits of the range is used (see Table 2.1 for fracture fluid volumes).

Other differences that may distinguish production of UFF from CFF are:

- The greater extent of the reservoir;
- The lower proportion of technically recoverable resource;
- The larger number of wells required per unit area and per unit of reserve;

- The use of multi-well pads and the size of well pads needed to accommodate multiple wells and HVHF; and
- The use of horizontal drilling (not always used in CFF).

The use of HVHF leads to differences with CFF in terms of increased:

- Water resource requirements.
- Energy consumption (and emissions to air from equipment).
- Waste water production.

CBM may be distinguished from CFF due to:

- The nature of the reservoir rock (coal) compared to the sandstones and carbonates typical of CFF;
- Coal being both the source rock and reservoir, whereas in CFF the hydrocarbon has migrated from the source to the reservoir;
- The way in which gas is held by adsorption, rather than in macropores;
- The generally limited thickness of the resources;
- The potentially shallower depth of the resource; and
- The need for groundwater pumping to desorb gas (groundwater pumping is not required for CFF).

A summary of criteria by which to categorise and hence distinguish between CFF and various UFF is presented in Appendix C; from the information, it is apparent that there is unlikely to be a single categorisation 'option' that captures all forms of UFF whilst avoiding capturing CFF. Potentially favourable options for categorisation could be based on the following (or combinations thereof):

- The permeability of the reservoir formation. It is interesting to note that in Germany a permeability of 0.6mD is used to determine the royalties payable. Higher royalties are payable above this value. The 0.6mD value is commonly used to establish the divide between CFF and UFF (Figure 2.2);
- Volume of water used in hydraulic fracturing (for shale gas, tight oil and tight gas). An appropriate value is likely to be in the range 1,000 to 10,000 m^3 per well;
- Injection pressure at the reservoir during hydraulic fracturing (for shale gas, tight oil and tight gas) e.g. more than 700 bar;
- Depth, due to additional risks presented by shallower operations (proximity to aquifers above wells) and deeper operations (greater pressures required for fracturing and the associated well integrity requirements);
- Depth for CBM (operations less than e.g. 1,000 m below ground level) as such operations are more likely to be near aquifers used for drinking water or contributing to surface water flow; and

- Volume of pumped groundwater for CBM (operations producing more than e.g. 20 m^3/day / well).

An option based on the volume of water used has the advantage of avoiding most CFF and capturing the principal activity that distinguishes UFF from CFF (i.e. *high* volume hydraulic fracturing). It is also closely linked to the risks and impacts of UFF. However, the volume used is important. If set too high it will only capture larger-scale operations and may potentially lead to industry tailoring operations to avoid the target. Further development and use of foams and gas for hydraulic fracturing may also render this option irrelevant.

Specifying a particular (high) injection pressure at the reservoir during hydraulic fracturing would enable capturing of UFF but may also capture some CFF. Pressure is related to depth however, and therefore this will potentially not capture shallower UFF operations, although risks and impacts are potentially similar and hence categorisation using pressure may be somewhat arbitrary. There is also a link between pressure and risks and impacts.

The use of depth to provide categorisation may capture most UFF except CBM. However, there is not a direct link to risk and impacts and therefore this may be seen as arbitrary. It will also capture CFF. The specification of a depth above which regulation is required links particularly to risks of groundwater pollution but is specific to CBM and is unlikely to be applicable to other forms of UFF.

2.3 Distinguishing Exploration and Production

The development of both CFF and UFF can be divided into a series of stages. Whilst CFF typically develops in sequential stages, UFF may be developed in a series of overlapping stages. CFF development generally follows a fairly well-defined sequence compared to UFF which can be less consistent and where development generally proceeds in a more incremental fashion. In UFF development, an operator may be exploring or appraising parts of a licenced area (concession) as well as developing and producing from another. The fluidity of the stages of UFF project development increases the complexity of the interactions required between the operator and regulator. For example, the regulatory system in most jurisdictions requires the submission and approval of a field development plan at the end of the exploration phase. The longer development curve for UFF makes it much more difficult to develop comprehensive plans, with the risk that relatively small subsequent alterations might trigger the need to resubmit and reapprove the entire development (IEA 2012).

In general terms, exploration seeks to identify whether there is a resource, to define its extent and then to demonstrate whether it is technically and economically viable to exploit. Where a resource has been demonstrated to be technically and economically viable then it will move into production, where production is the process of extracting the hydrocarbon for use. The stages in CFF and UFF exploration and production are presented in Table 2.2. These phases can be broken down into a number of subphases that are generally recognised within the industry.

Table 2.2 Stages in CFF and UFF Exploration and Production

Stage	Sub-stage	Main Activity in Stage	Subsidiary activities	Typical duration	Scale of operation
Exploration	Identification of resource	Compilation and review of existing information (e.g. by government / geological survey / oil company)	Strategic Environmental Assessment before licensing and exploration (e.g. UK and Lithuania – Milieu, 2013)	Ongoing activity	
	Licensing	Tendering of exploration licence		Ongoing activity	
	Non- intrusive exploration Evaluate reservoir potential. Identify geological structures (UFF specific)	Non-intrusive geophysical testing (i.e. without drilling)	Review of existing data	0.5 to 2 years	
			Geophysical investigation		
			Initial conceptual model		
	Intrusive exploration (i.e. with drilling) Determine whether hydrocarbons are present and potential productivity	Drilling of vertical and possibly horizontal wells to collect core samples for geological appraisal, hydrocarbon content, mineralogy	Baseline surveys (ecology, hydrology, groundwater, community impact)	1-3 years	1 to 5 wells per licence area (1 to 5 well pads)
			Mobilisation of drilling rig and equipment and people to the drill site		
			Well pad construction		
			Drilling of vertical or deviated wells to gather cuttings, core, wireline and fluid data		
			Trial of hydraulic fracturing. May include flow or injection testing		
			Revised conceptual model and resource estimate		

Stage	Sub-stage	Main Activity in Stage	Subsidiary activities	Typical duration	Scale of operation
Appraisal	Test and optimise completion techniques (UFF specific) and flow rates. Evaluate technical and economic viability.	Appraisal	Mobilisation	1-5 years	5 to 20 wells per field / 2 to 5 well pads (more wells required for UFF than CFF)
			Well pad construction		
			Drilling (vertical)		
			Drilling (horizontal)		
			Casing installation		
			Well completion / fracturing		
			Flowback		
			Flow testing		
	Assessment Evaluate technical and economic viability for the whole project and develop plans for production	Extended flow testing	Final reserve estimate	1-2 years	
			Development plan		
	Licensing Apply for licence for production	Production licence			
Development and production	Extract oil and gas for production purposes. Many more wells will be drilled for UFF than for CFF at more locations and at a higher density of locations per unit area	Production wells	Planning	7 to 40 years	10 to 1,000 wells 2 to 100 well pads
		Multiple pads and wells	Pad preparation		
		Drilling and fracturing	Drilling (vertical/ horizontal drilling), casing & completion, fracturing & flowback management)		
		Production			
		Infrastructure	Water provision		
			Pipelines and / or tankers		
			Wastewater collection and transport		
			Wastewater treatment		
			Hydrocarbon collection and distribution		

Stage	Sub-stage	Main Activity in Stage	Subsidiary activities	Typical duration	Scale of operation
Decommissioning , restoration and aftercare			Decommissioning of above ground equipment and reclamation		
			Plugging of wells		
			Removal of well pads		
			Monitoring		

Notes: The different phases of the exploration process listed in the above have been compiled and adapted from Milieu, (2013), CSUR (undated), DMEA (2013), and UKDECC (2013). This considers development for an entire field (or concession).

Exploration typically begins with a desk study, where all available data and information are collated and used to construct a conceptual model of the possible play. The focus at this stage is on geology and geological structures, looking for reservoirs (with potential for gas generation), sealing layers to identify prospective areas. The results of previous exploration efforts may be examined at this stage.

In the majority of cases, further data collection is then undertaken using non-intrusive surface geophysical techniques such as seismic surveys and airborne geophysics to determine the structural composition, configuration and faulting of the deep subsurface.

CFF exploration in particular is focussed on identifying specific geological structures that can retain hydrocarbons, in combination with a reservoir. CFF exploration then proceeds to drilling of a small number of exploration wells to test whether there is accumulation of hydrocarbons. For UFF, specific geological structures are not necessary and the entire reservoir is the prospect but exploration may aim to identify ‘sweet spots’ where gas flows are higher. Early exploration wells for UFF are used to collect core samples and to take measurements in the rock but are not typically subject to hydraulic fracturing. However, later exploration or appraisal wells may be hydraulically fractured to determine whether gas or oil is present and to test flow rates. Appraisal and production are distinguished by their different objectives but also through their relationship to licensing and permitting requirements. In terms of the technical criteria that distinguish appraisal and production the main difference is in the scale of operations at the scale of the concession. Appraisal typically involves drilling and stimulation of a relatively small number of wells, compared to production. The number of wells is sufficient to obtain samples, test the size of the resource (depth and area) and to demonstrate technical and economic viability. In contrast, production seeks to exploit the whole resource to the extent that it is technically and economically viable to do so. Production is likely to extend over many years, (20 to 40 years) whereas exploration will be time-limited (often by the terms of exploration licences). It should be noted however, that compared to CFF, UFF is a relatively young industry, in which most production has taken place in the last 10 years. In addition, there have been changes in production methods since the earliest wells were drilled. Consequently, typical well decline rates and lifetimes are not well defined (Sandrea, 2012). For UFF, production at each well peaks early in the life of the well and then shows a long-term decline, with initial decline rates of 60% to 80% per year in the early years (Standard and Poor,

2011) for US shale gas plays. Total production per well varies but is estimated to be in the range 3 to 10 billion cubic feet (85 to 283 million m^3) per well (Standard and Poor, 2011) for a range of US Shales.

The scale of operations at an individual well pad will be similar at the appraisal stage, to the scale of operations at the production stage. For instance, evaluation wells proposed by Cuadrilla (Cuadrilla Elswick, 2014) at sites in Northwest England will involve the drilling and hydraulic fracturing of four wells per single pad at two pads followed by extended flow testing for up to one year. The drilling and hydraulic fracturing operations only differ from production in terms of the number of wells and duration of these operations.

The differences at the scale of the concession in terms of both extent and timescale mean that production is more likely to incorporate permanent infrastructure in the form of roads, pipelines, gas production facilities and wastewater treatment facilities, whereas appraisal is unlikely to.

A review of regulatory provisions governing key aspects of unconventional gas extraction (Milieu, 2013) examined provisions in the United Kingdom, Spain, Bulgaria, Denmark, Germany, Poland, Lithuania and Romania. In terms of distinguishing exploration and production, the review found that the permitting system for exploration and extraction of UFF was the same as for CFF.

A number of stages can be defined across the well and field lifecycle. AEA (2012) summarised these stages as:

- Stage 1: Site identification and preparation. Site preparation activities consist primarily of clearing and levelling an area of adequate size and preparing the surface to support movement of heavy equipment plus design and construction of access routes;
- Stage 2: Well design; drilling; casing; cementing; perforation. The first drilling stage is to drill, case, and cement the conductor hole at the ground surface. A vertical pipe is set into the hole and grouted into place. The second drilling stage is to drill the remainder of the vertical hole. Surface and intermediate casings are constructed, cemented and horizontal bores drilled. The pipework and cement is then perforated, and the wellhead constructed;
- Stage 3: Technical hydraulic fracturing. Water with proppant (typically sand) and chemicals is pumped into the well at high pressure;
- Stage 4: Well completion and management of wastewater. During the well completion phase, operators need to process flowback and produced water;
- Stage 5: Production. Gas is extracted and put into supply. Produced water is separated from the gas and disposed of; and
- Stage 6: Decommissioning/abandonment.

Within each of these stages there are multiple activities, for example for the hydraulic fracturing stage the following sequence of events takes place (CSUR, undated):

- Mobilise equipment and fluids to site;
- Acid treatment of the well;

- Flush well;
- Perforate production tubing;
- Rig up equipment;
- Pump fluid and proppant; and
- Flush well.

Hydraulic fracturing in horizontal wells is typically undertaken in stages for discrete intervals of the lateral; up to 20 hydraulic fracturing stages may be used. This process typically starts at the furthest extremity of the well and works backwards. Each of these stages can be further broken down into sub-stages. A typical sequence might involve (ALL Consulting, 2012): pumping of freshwater to clean out the well followed by an acid flush to remove cement from perforations, then a mini-fracture with water then a shut in to measure the formation response, then fracture fluid is injected (without proppant), then the proppant is introduced.

There are only limited technical differences between exploration and production, for example wells are drilled and hydraulically fractured using the same methods. The key distinctions and potential criteria to distinguish between the stages are:

- Purpose of operation. For UFF, whilst appraisal of well flow rates requires fracturing and associated activities and infrastructure (albeit at a reduced scale and not necessarily permanent), the purpose of the operations is not for full-scale production;
- Scale of operations. For UFF, production may involve activities at a number of pads and also the drilling and fracturing of multiple wells at a single pad. In this situation, operations at a single well pad may continue for months to years and operations across a well field will take place over many years;
- Infrastructure requirements. Production of UFF will require additional infrastructure to deliver water and remove gas or oil and wastewater. This infrastructure may include pipelines (e.g. for gas export) and roads (e.g. for water and wastewater transport and oil export). In contrast, exploration will largely use road transport; and
- Production may also involve the construction of centralised infrastructure.

Summary

The overall exploration and production of both CFF and UFF follow a similar process, although there are differences in detail of what activities take place in different phases and in the scale of those activities as set out in Table 2.2. Whilst CFF typically develops in sequential stages, UFF may be developed in a series of overlapping stages. There is a distinction between the exploration and production phases of both CFF and UFF in terms of the activities and scale of activities and in licensing and permitting. Exploration and resource appraisal for UFF involve drilling and stimulation, the key difference to CFF being the scale of operations. The differences at the scale of the concession in terms of both extent and timescale mean that production is more likely to incorporate permanent infrastructure in the form of roads, pipelines, gas production facilities and wastewater treatment facilities, whereas appraisal is unlikely to. In some cases appraisal may involve extended testing or early production hence the boundary with production may be transitional. The key activities are when hydraulic fracturing occurs and when production commences.

3. Comparison of Risks and Impacts of other UFF with those of Shale Gas

3.1 Introduction

In Section 2 the technical characteristics of other UFF were compared to shale gas to highlight the similarities and differences. In this section, other UFF are assessed to identify and group similar types of risks and impacts.

The geological and technical aspects discussed in Section 2 can play a role in categorising UFF. However, such criteria are limited in their capacity to provide categorisation from the perspective of environmental risk and impacts. To enable categorisation by risks and impacts, context needs to be taken into account, for example the scale of operations, environmental conditions and operating practice. The basis of the risk comparison is set out in Section 3.2 and the use of an illustrative concession concept to provide a representation of the scale of operations is described in Section 5.2.1. The comparison with shale gas risks and impacts presented in AEA (2012) used 'per well' as a starting point whilst remaining mindful of cumulative risks; the aim being to identify where risks may potentially differ so that required adjustments and further developments could be made to measures to enable assessment of potential policy option costs.

In this section, a critical risk assessment of other UFF is provided together with the scale of likely impacts in comparison to the risks and impacts for shale gas. This information is then used in Section 4 to identify whether the measures considered for shale gas are appropriate and proportionate to manage the risks from other UFF. The categorisation of risks and impacts has the following objectives:

- Development of a risk matrix for assessment of risks for other UFF compared to shale gas; and
- Comparison of the risk and impact profiles of each other UFF group with risks and impacts of shale gas activities.

The risks and measures for shale gas are presented in detail in AMEC (2014) and AEA 2012, the assessment should be read in conjunction with the detail presented in these studies.

3.2 Approach

3.2.1 Introduction

A two stage approach was developed encompassing:

1. A screening stage: identification of risks and impacts of other UFF to take forward to the risk assessment and impact evaluation stage by comparing the risks and impacts identified for shale gas with those arising from other UFF;

2. Risk assessment and impact evaluation stage: consideration in greater detail of the risks and impacts of other UFF that were not screened out in the first stage, or which were identified as additional risks compared to those identified for shale gas. This enabled the identification of those risks for which the appropriateness and proportionality of measures already identified for shale gas needed to be evaluated.

This approach involved the development of a risk matrix by which to qualitatively rank the risks identified. A qualitative approach was used due to the lack of quantitative data available across the range of stages and activities for UFF. The comparison with shale gas was based on the per well risks whilst remaining mindful of cumulative risks and resulting development footprint arising from concession development, with the aim being to identify where risks may potentially differ so that required adjustments to measures could be made. Risk assessment studies such as those by Umweltbundesamt (2013) and also (for CBM in particular) by the Environment Agency for England (2014b) and BRGM (2014) were reviewed to provide further information on the characteristics of risks presented by other UFF.

3.2.2 Stage One: Screening

The screening stage of the process compared the risks and impacts identified for shale gas with those arising from other UFF, specifically tight gas, tight oil and CBM. In the cases where the level of risk was expected to be comparable to shale gas the risk was screened out of the process, because the measures for shale gas are likely to be appropriate for the other UFF in these cases. Only risks that were different to those of shale gas; or those where the other UFF risk was new proceeded to the second stage of the assessment.

The screening process involved the following steps:

1. A high-level identification of risks and impacts. These were grouped into categories to allow comparison with published work on the risks and impacts of shale gas. Categories were assigned on the basis of the stages identified in AEA (2012), which follows the development cycle at a single well pad including exploratory stages, followed by well completion, production and ultimately well abandonment phases;
2. Comparison of risks and impacts. Risks and impacts were classified by comparison to shale gas as 'comparable', 'potentially more significant' or 'potentially less significant'[16]. The comparison was based on literature and expert judgement. Where risks and impacts were identified as 'comparable' then no further assessment was undertaken, whereas non-comparable risks were taken forward for assessment of measures;
3. Identification of new risks and impacts. Due to the differences between the ways in which other UFF are developed, there are potentially some additional risks and impacts to those identified for shale gas. Where

[16] Comparable - expected to have similar magnitude and frequency to shale gas. Potentially more significant - expected to have greater magnitude and/or greater frequency than shale gas. Potentially less significant - expected to have lower magnitude and/or lower frequency than shale gas. For example, if an UFF has a much lower injected water volume requirement for fracturing than shale gas, the risk related to water resource depletion is potentially less significant due to lower magnitude. The term 'potentially less significant', does not mean that a risk is guaranteed to be smaller as the scale of operations could be the same as for shale gas (which is possible) and so measures may be required to be the same/similar as the risk level may be comparable to that of shale gas..

additional risks and impacts were identified for other UFF they were assigned to development stages and grouped in the same way as the risks and impacts for shale gas.

The completion of the screening stage provided a 'screened list' of risks and impacts to take forward to the risk assessment and measure evaluation stage.

3.2.3 Stage Two: Risk and Impacts Assessment Evaluation Stage

The objective of this stage was to consider in greater detail the risks and impacts of other UFF that were identified as non-comparable with those of shale gas (potentially more or less significant), or which were in addition to those identified for shale gas. The purpose of this exercise was to identify those risks for which the appropriateness and proportionality of measures already identified for shale gas needed to be evaluated.

Risk Matrix

A risk matrix (Figure 3.1) based on King (2012), which is similar to that set out in AEA (2012) was used to score risks. The matrix is not identical to that used in AEA (2012) as it incorporates subsequent developments e.g. in terms of number and type of descriptions of risks and impacts developed in AMEC (2014) study on shale gas. The matrix in Figure 3.1 has been adapted to retain the salient elements of the table presented by King and AEA but with further tailoring of the descriptions to help retain continuity with the AMEC (2014) study. The matrix provides a systematic approach to assess risk based on the likelihood that an incident will occur and the potential consequence of that incident. The matrix scores risk as the product of likelihood and consequence. The highest scores are given to combinations of high likelihood and catastrophic consequence (and vice versa). The risk score permits risks and impacts to be compared.

Risks and impacts for each category were assessed qualitatively based on expert knowledge informed by the literature where possible. In a number of cases the literature reviewed provides anecdotal experiences of UFF or estimated values. Where possible the risks were reviewed using the quantitative data available. Where this was not the case the available literature was considered as it provides valuable industry insight into the nature of the activities and risks presented. For those risks that are similar to shale gas but which differ for other UFF in terms of likelihood or scale of consequences the focus of the assessment was on identifying whether the risks are potentially higher or lower for other UFF compared to shale gas.

The approach then adopted the following steps to use the risk matrix in evaluating the identified risks from Task 1:

Step 1: Consider the AEA (2012) assessment of risks. The AEA work characterises the potential risks that would occur if specific mitigation in relation to the risks posed by shale gas extraction (i.e. specific to shale gas only) are not implemented.

Step 2: Based on the AMEC (2014) work on shale gas and considering further mitigation where measures are *likely to be applied*, consider whether the AEA (2012) risk ranking needs to be adapted.

Step 3: Map the results of steps 1 and 2 onto the risk matrix developed for this study.

Step 4: Review other UFF types to consider whether risks are comparable or potentially smaller/greater than for shale gas.

Measures that mitigate environmental risk may already be expected to be adopted by operators (e.g. due to standard industry practice, or to minimise financial risk of investments). It was assumed therefore, that measures that are *likely* to be applied[17] by operators are in place to mitigate risk when using the matrix to assess the degree of risk (part of steps 2 and 4).

The consequences of the risk were assessed in terms of impact on the environment only, and effects on humans via environmental pathways. The evaluation did not assess direct human health risks from incidents as this was specifically excluded from the study terms of reference. The definitions derived for consequences and risks are based on the nomenclature of King (2012) and AEA (2012) with some further interpretation to account for the setting of other UFF. This additional tailoring of descriptions and scope was necessary to allow the matrix to be used for all UFF types; and strikes a balance with a recognised and previously used system within the current context of this study.

Figure 3.1 Risk Matrix

			Consequence of Incident					
			1	2	3	4	5	
			Slight	Minor	Moderate	Major	Catastrophic	No data
Likelihood of Incident	1	Extremely Rare	1	2	3	4	5	Not classifiable
	2	Rare	2	4	6	8	10	
	3	Occasional	3	6	9	12	15	
	4	Likely	4	8	12	16	20	
	5	Highly Likely	5	10	15	20	25	
		No data	Not classifiable					

Key

Colour	Level of Risk	Score
Green	Low	1 – 4
Yellow	Moderate	5 – 8
Orange	High	9 – 12
Red	Very High	15 – 25

[17] See section 3 and Table E2 in Appendix E of AMEC (2014).

Consequence

Consequence was assigned as follows:

- **Slight.** These are incidents which will have immediate but short term impact on the environment which naturally remediate after a few days/weeks. Where the severity is 'low', it would have direct impact on environment with noticeable effects, but these would be limited, i.e., not causing death of flora and fauna. An example of a short term, low severity incident within the 'slight' category is drilling equipment running with poor efficiency causing a short term spike in the concentration of air pollutants (such as oxides of nitrogen and oxides of sulphur) which would affect people and the environment. Once the issue was rectified effect on people and environment would return to pre-incident conditions within a few hours/days.

- **Minor.** These are incidents which will have both an immediate and longer term effect (e.g. weeks/months) and take a number of months for the environment to naturally remediate, or require physical intervention to remediate the effects. The level of severity is again 'low', i.e. they will have a noticeable effect on environment without causing widespread death of flora and fauna. An example of an intermediate term, low severity event is a minor leak from the well head which causes land contamination by produced fluid.

- **Moderate.** These are incidents which will have an immediate and long term (e.g. years) effect on the environment. Severity will be 'low', including chronic but not fatal effects on the environment. An example of a long term, low severity incident might be a loss of produced water at surface level (containing remaining fracturing fluids and other contaminants) into waterways causing an increase in concentrations of NORM and metals in river sediments. Effects will be likely to last for several years without direct intervention but dilution rates will limit the effects of the raised levels.

- **Major.** These are incidents which will have an immediate effect both on a short term basis (hours/days) and also longer term (weeks/months/years). However these events can be remediated with direct intervention within a number of weeks of the incident. The level of severity in these incidents will be high causing widespread death to flora and fauna with significant impact on ecosystems and local populations, but with managed response the effects should be short term. An example of a short term high severity incident classed as 'Major' may be a spillage of large volumes of undiluted chemicals into a waterway causing severe effects on aquatic health.

- **Catastrophic.** These are incidents which will have an immediate and prolonged effect on the environment lasting several years. The effects of the incident will be severe and widespread causing death to flora and/or fauna or irreversible damage to the environment for several years. The incident is also potentially likely to damage natural resources in an irreversible fashion requiring several years for the environment to return to pre-incident conditions. An example of a long term, high severity incident might be extensive contamination of a groundwater aquifer with hazardous and non-degradable fracturing chemicals.

Likelihood

The following likelihood categories have been used. The assessment assumes that mitigation measures likely to be applied by industry (BAU measures) are in place[18]. Cases where such measures are not in place would have a higher likelihood.

- **Extremely rare.** No known events of the risk under review have taken place within the industry within Europe or elsewhere.
- **Rare.** Incidents may have occurred within the industry (Europe or elsewhere) previously but at a very low frequency.
- **Occasional.** These are incidents that should not occur under standard practices. These incidents will however be more common place, for example those that are known to have happened historically at several companies during operations in Europe or elsewhere.
- **Likely.** These are incidents which are likely to occur. The frequency of events is more difficult to predict, but should be assumed to have happened several times per year at different operating companies.
- **Highly likely.** These are incidents which are highly likely to occur. The frequency of events is more difficult to predict, but should be assumed to occur several times per year (or all the time) in each well location. Incidence of the issue is well documented within the industry with good practice guidelines warning of its potential.

3.3 Stage One: Screening

The assessment of risks and impacts for other UFF and the comparison to shale gas involved grouping risks into the stages of exploration and production described in Section 2.3 for consistency with the six stage approach in AEA (2012). The risks and impacts for the other UFF (tight gas, tight oil and CBM) have been reviewed against these stages. For each of the stages a range of aspects were examined[19]:

- Groundwater contamination;
- Surface water contamination;
- Water resource depletion;
- Air[20];
- Land take;
- Biodiversity;

[18] See section 3 of AMEC (2014) for a full description of the approach and Appendix B of this report.

[19] Regarding potential risks to soil quality, these are accounted for within groundwater contamination and surface water.

[20] Includes emissions of greenhouse gases.

- Noise;
- Visual Impact;
- Seismicity; and
- Traffic.

Screening Results

The results of the screening phase consider the main differences in risks and impacts, at each stage, between shale gas and other UFF. The results show that the differences are predominantly within the technical hydraulic fracturing, well completion and production stages.

The results also show that CBM is more markedly different than other types of UFF when compared to shale gas and also different from tight gas and tight oil. These differences arise due to the different properties of the reservoir (coal is typically thinner and more brittle than shale and tight sand), the typically shallower depth, the lower pressures for hydraulic fracturing, and the higher quantity and different characteristics of produced waters associated with the requirement to lower hydrostatic pressure. Those stages marked as 'comparable', had no specific risks that resulted in impacts that were significantly different to shale gas and thus no risks from these highlighted stages were carried through to stage 2 of the risk assessment.

Table 3.1 provides a full breakdown of the results of the screening stage. A discussion for each UFF and stage of the fracturing process provided below. To avoid repetition, tight gas and tight oil are discussed together with specific differences relevant to this study indicated (e.g. where gas and oil present contrasting risks or impacts due to the difference in the nature of the hydrocarbon).

Tight Gas and Tight Oil

The extraction of tight gas and tight oil follows closely related processes to those seen for shale gas. As such the associated risks and impacts from these processes will also be largely similar. The results of the screening process for tight gas and tight oil are therefore discussed here together out of practicality. There are differences for tight oil in surface processes due to differing production and export requirements however, these are comparable with conventional oil operations and hence are BAU and addressed through existing industry practice and regulatory requirements (such existing practices are not the main focus of this study). Where differences arise in the risk screening of tight gas and tight oil, this is indicated.

The screening process involved reviewing the identified risks and impacts based on the six stages of the process outlined in Section 2. The findings of this screening process are summarised below. The stages are consistent with those used in AEA 2013 to ensure a consistent approach. The typical duration and scale of operations over the lifecycle stages of development are indicated in Table 2.2.

1. Well pad site identification and preparation

The identification of suitable sites for well placement, preparation of ground and movement of materials using heavy equipment are all processes which mirror the technical requirements of site preparation for extraction of shale gas. The associated risks and impacts of these processes will also therefore be mirrored between shale gas activities and those seen for tight gas and tight oil. In terms of the scale of the activity tight oil and tight gas may have comparable pad size to shale gas and concession size for tight gas and tight oil could potentially be of a similar size[21] to that anticipated for shale gas, with the size of the geological formation being the limiting factor (Centrica, 2010). Consequently risks presented at this stage are considered comparable.

2. Well design, drilling, casing and cementing

Tight gas and tight oil will follow the same processes as for shale gas during the drilling, cementing of pipes and establishment of wells prior to fracturing. These processes use the same technology during the development of pads and wells prior to the hydraulic fracturing stage. Due to these similarities in the nature and scale of activity the associated risks and impacts will also be similar between shale gas extraction and tight gas and tight oil. Therefore the risks identified during this stage of the process will be comparable with those seen for shale gas.

3. Technical hydraulic fracturing stage

The hydraulic fracturing process for tight gas and tight oil is broadly similar with the main difference being the volume of fluid required during fracturing. Ranges of required fluid for fracturing per well per fracturing event are (see Appendix A) based on information from a review of literature:

- Shale gas 7,600 – 34,100 m^3 (estimate 15,000m^3)
- Tight gas 100 – 12,000 m^3 (estimate 6,000m^3)
- Tight oil 500 – 25,600 m^3 (estimate 11,400m^3)

This demonstrates that as a range, the values broadly overlap between shale, tight gas and tight oil (the variation partly influenced by formation depth and horizontal distance of the well, e.g. with the Bakken oil play wells being longer than for shale gas as are tight gas wells in the US Rockies gas play). However based on an ‘estimate’ for water demand during fracturing, tight oil and tight gas require less water, this is particularly the case for tight gas which is significantly lower than tight oil and shale gas. The associated risks and impacts for water resource depletion within tight gas and tight oil operations may also be correspondingly potentially less significant than for shale gas (assuming the same location specific water resource availability conditions); noting the marked difference between tight gas and shale in particular. On this basis the volume of traffic required to transport water to site would also be potentially lower than shale gas operations. This in turn would result in potentially less significant risks and impact from traffic to and from site during the hydraulic fracturing stage.

For tight oil, it is possible that risks and impacts on groundwater contamination arising from migration of oil underground could be potentially less significant (rather than comparable as for tight gas) than for shale gas as the

[21] Note however that current tight gas operations in Germany are of limited scale.

heavier hydrocarbon will be less mobile in the underground environment than is the case for tight gas. For groundwater contamination arising from surface operations (e.g. due to spills), risks and impacts are potentially more significant than for shale gas due to the liquid rather than gaseous nature of the hydrocarbon that will require contrasting risk mitigation measures (e.g. to prevent and/or control spillage). On balance taking account of BAU risk mitigation measures[22], risks and impacts for tight oil are judged comparable to tight gas.

4. Well completion

The well completion stage includes those activities post-fracturing and in preparation of gas/oil production and capture. Reported percentage flowback volume ranges are (see Appendix A):

- Shale gas 50%[23]
- Tight gas 17-35% (estimate 25%)
- Tight oil 10-60% (estimate 35%)

Again values are presented as a range with a degree of overlap particularly for shale gas and tight oil. The 'estimate' for flowback suggests that tight oil may produce less flowback than shale. For tight gas the flowback expected from fracturing processes is lower than shale gas. This may lead to smaller volumes of flowback which have to be managed during the well completion stage and hence potentially less significant related risks for tight gas. For tight oil, flowback may have different composition to shale gas as heavier hydrocarbons (oil) may be present. Oil water mixtures are easily treated by separation and will be a BAU requirement under existing practice and regulatory requirements[24] hence risks arising from flowback remain comparable overall, once the impact of BAU measures is taken into account. The key difference in this case will relate to the volume of traffic assuming flowback is removed from site using tankers.

As noted above under the technical hydraulic fracturing stage, it is possible that risks and impacts on groundwater contamination for tight oil may differ from shale gas but on balance are judged comparable overall.

5. Production

During the production stage gas/oil is collected from the wells. This will involve similar processes and associated risks for shale gas operations as for tight gas and tight oil. Typically during this phase the flow of gas/oil is determined by a variety of factors relating to the geological nature of the well. Re-fracturing may be required to maximise production from a well and extend the useful life span of producing wells. Tight gas operations are expected to potentially require less water than shale gas operations during the fracturing stage (ICF, 2013), it is likewise assumed that less water would also be required for re-fracturing activities. Just as within the technical hydraulic fracturing stage the reduced water requirements for tight oil and tight gas means that the burden and associated risks on water resource depletion will be potentially less significant than seen in shale gas. Equally the

[22] E.g. tank bunding, double-skinned storage tanks, tank level alarms, provision of spill kits, impervious underlay to the site and monitoring arrangements.

[23] 50% was used in AMEC (2014) as a reference point referring to work carried out by the Joint research centre. A range of 0-75% has been reported (AEA (2012)).

[24] I.e. the requirement to meet Water Framework Directive requirements and related discharge consent conditions for treated wastewater.

volume of traffic required to transport these materials (i.e. water used for fracturing and waste water) to and from site will also be potentially less significant resulting in reduced impact and risks associated with traffic. Traffic will also be associated with the management of produced water from the well during production. Produced water generation is highly variable[25] in UFF formations depending on a range of factors such as conditions at the time of deposition, rock porosity and connections to groundwater systems. Traffic associated with produced water management for tight gas is assumed to have a similar range of activity as that for shale gas.

As noted above under the technical hydraulic fracturing stage, it is possible that risks and impacts on groundwater contamination for tight oil may differ from shale gas but on balance are judged comparable. In addition, as noted under the completion stage, risks and impacts arising from flowback from tight oil remain comparable; the same will also be the case for risks and impacts from produced water where oil may also be present. For tight oil, infrastructure to capture gas from tight oil is assumed to be in place in line with Recommendation 2014/70/EU (European Commission 2014)[26]; and regarding traffic, although there will be increased releases to air arising from trucks required to transport oil (pipeline transport is not assumed), flowback generation (from assumed refracturing in the production stage) is lower than for shale gas (see technical hydraulic fracturing and completion stages above), hence risks and impacts are judged comparable to shale gas.

Regarding tight oil, there has been issues raised in North America regarding the risks of handling of oil from tight oil wells compared to those of handling oil from conventional wells stemming from accidents in the transportation of oil from tight oil wells in the Bakken formation. The incidents with the Bakken formation relate to a series of derailments of railway trucks during 2013-14 resulting in oil spills and in some cases, fires. The accidents were a result of poor railway operating practices and infrastructure and incorrect hazard classification of the oil. This resulted in an emergency order being placed on the transportation of crude oil from Bakken shales by rail with specific conditions[27]. Tight and shale oil from Bakken and Eagle Ford are characterised by batch to batch variability, gravity ranges of 20-55^{o} API (i.e. can be heavy or light crudes), low sulphur levels, potentially elevated H_2S and may contain dissolved gas (methane). This variability (and associated issues of corrosivity and flammability) is found across the continuum of crude oil, whether from tight/shale formations or conventional formations. Crude oil extracted by conventional methods may also contain highly volatile gases, and corrosive substances (e.g. sour wells in the North Sea with high H_2S levels). The issues with oil from Bakken shales is related to poor practice in incorrect classification of materials (against existing regulations) and poor railway operating practices and infrastructure resulting in railroad accidents involving light crude containing light fractions with low flashpoints. Such risks may also be associated with oil produced from conventional wells and hence are not specific to oils from tight formations.

[25] E.g. Mantle (2011) indicates ranges of 0.03-0.13 litres produced water/m3 gas with variations also across the early and later stages of well life cycle.

[26] This states that Members States should ensure that if an installation's primary purpose is producing oil using high-volume hydraulic fracturing, specific infrastructure that captures and transports associated natural gas should be installed.

[27] Recommendations were made in early 2014 by the Department of Transport's (DoT's) Pipeline and Hazardous Materials Safety Administration (PHMSA) regarding properly classifying hazardous materials and reviewing railroad operating practices (e.g. speed restrictions, braking signal propagation systems, routing analyses, additional track and rail integrity inspections, more frequent mechanical inspections). The PHMSA issued a Safety Alert, noting the potential variability of crude oil (and that such variability may affect the integrity of packaging or present additional hazards related to corrosivity, sulphur content, and dissolved gas content). Due to concerns over improper classification and packaging of crude oil, the DoT also issued an Emergency Order requiring all shippers to test products from the Bakken to ensure the proper classification of crude oil in accordance with the Hazardous Materials Regulations (HMR) before it is transported by rail, while also prohibiting the transportation of crude oil in the lowest-strength packing group (the Emergency Order can be accessed here: http://www.dot.gov/briefing-room/emergency-order).

6. Well abandonment

The final management and closure of a well site once gas/oil production has fallen below viable levels will involve a similar set of activities and processes for tight oil, tight gas and shale gas operations. As these activities and the associated risks and impacts are broadly similar regardless of the UFF type the identified risks for this stage will be comparable to those for shale gas. The screening process therefore did not identify any specific items to carry forward into the subsequent risk evaluation stage.

Coal Bed Methane

The processes, activities and associated risks and impacts for CBM are markedly different from tight oil and tight gas, and also for shale gas operations. This reflects the differences in drilling depth and well arrangements, geology of the rock associated with CBM and required process of gas extraction. The results of the screening stage are summarised below.

1. Well pad site identification and preparation

As with the other types of UFF and shale gas operations, the identification and preparation phase involves the management of surface operations, including excavation and development of well pads for drilling. However CBM operations will typically have smaller well pads than the other types of UFF mentioned (Halliburton, 2008). The Environment Agency for England (2014a) quotes 0.5 hectares per pad. The smaller scale of the operation and equipment required means that the burden on traffic will be potentially less significant than for shale gas operations. Equally the associated air emissions with heavy fuel powered equipment would be expected to be potentially less significant than for shale gas, either through the smaller size of equipment, shorter duration of work, or both. The 'land take' aspect is more difficult to evaluate: smaller pad sizes should potentially mean reduced land take, however Ewen et al. (2012) suggest that CBM wells form a different arrangement to tight gas, tight oil and shale, with multiple vertical wells grouped together and then branching out horizontally below ground to allow fracturing. This makes it unclear whether potential land take is genuinely smaller than shale gas or broadly comparable.

2. Well design, drilling, casing and cementing

During the establishment of wells, including the drilling of boreholes, the shallower depth used for CBM will be the key difference between CBM and shale gas operations. The shallower depth means that smaller rigs are required to drill and less material is required for casing and cementing due to shorter wells. The CBM operation carried out within Falkirk, Scotland[28] also suggested that during the well drilling stage, due to shallower depth, the work was able to be completed in a shorter time than typically seen in shale gas operations. Within the Falkirk CBM operation each vertical well was completed within 14 days with four horizontal bores completed by an additional 90 days (in total 22.5 days per horizontal bore) (Dart Energy, 2012)[29]. As a comparison AMEC (2014) quotes shale gas operations taking up to 27 days per vertical well and 25 days for each horizontal bore drilled. The shorter drilling period and smaller equipment will mean the potential risks and impacts for releases to air from

[28] Note that the Falkirk operations do not include hydraulic fracturing.

[29] Reduced material requirements and timescales relate to shallower depths rather than the absence of fracturing.

power generation plant would be potentially less significant than seen with shale gas. Equally the reduced need for materials would mean a reduction in the volume of traffic and potentially less significant associated risks and impacts compared to shale gas.

3. Technical hydraulic fracturing stage

During the fracturing stage of the process the key elements that differ from shale gas operations are the depth at which fracturing occurs within the rock and the volume of fluid required for fracturing. These aspects may both increase and decrease the associated specific risks and impacts for CBM (in different ways) compared to shale gas. CBM fracturing typically occurs at a shallower depth (500 to 1,500 m, see Table 2.1) than shale gas (e.g. 3,000 m) which places it closer to groundwater resources. There will therefore be less separation between CBM and water resources than is the case for most tight oil, tight gas and shale operations. The associated risks and impacts for groundwater contamination are therefore potentially more significant for CBM compared to shale gas (if not mitigated effectively). Equally the risk of fugitive emissions from CBM finding their way through rock strata to the surface is potentially more significant for CBM compared to shale gas operations. This reflects the typically shallower depth of the fracturing and a potential for a more significant risk of fugitive gas seepage through rock within CBM operations (Ewen et al. 2012). In contrast, there is potential for groundwater contamination risks and impacts arising from migration of gas and groundwater migration from deeper CBM target formations (i.e. at a depth of 1,500m or more) to be comparable to shale gas (due to a greater distance from groundwater sources and an increased potential for geological barriers resulting in a impeded or obstructed risk pathway).

Ranges of required fluid for fracturing per well in both CBM and shale are (see Appendix A):

- Shale gas 7,600 – 34,100 m^3
- CBM 0 – 4,700 m^3

Lower volumes of water are required during the fracturing operations for CBM compared to shale gas. The reduced water demand will mean that the risk of water resource depletion for CBM is potentially less significant than for shale gas. Equally, lower water requirements during fracturing will reduce the number of vehicles required to transport material to and from site and hence traffic burden and its associated risks and impacts for CBM will be potentially less significant than that seen within shale gas operations.

4. Well completion

The well completion stage will include those activities post-fracturing before gas generation commences. This includes the management of flowback. As CBM requires lower quantities of water during fracturing compared to shale gas operations, the volume of fluid as flowback will also be correspondingly less. Reported percentage flowback volume ranges are (see Appendix A):

- Shale gas 50%
- CBM 61-82%

Whilst percentage flowback is higher, volumes will be lower due to the lower volume of water injected and hence the volume of traffic required to remove wastewater for treatment is lower. The traffic burden and associated risks and impacts for CBM will be potentially less significant than for shale gas.

5. Production

During the production stage, to maximise production and extend life span of wells, operators may carry out re-fracturing. The reduced water demand requirements (compared to shale gas) highlighted during the fracturing stage is likely to mean that water demand during re-fracturing is also lower for CBM compared to shale gas. This means that the associated risks and impacts for water resource depletion will be potentially less significant for CBM compared to shale gas.

Conversely the shallower depth of fracturing for extraction of CBM and closer proximity to groundwater resources means that the risks and impacts for groundwater contamination and fugitive emissions to air from seepage in rock are potentially more significant for CBM compared to shale gas operations. However, for deeper CBM target formations (i.e. at a depth of 1,500m or more) the potential for fugitive emissions to air from gas migration is likely to be more comparable to that of shale gas due to a greater depth and an increased potential for geological barriers resulting in a impeded or obstructed risk pathway. There is potential for groundwater contamination risks and impacts arising from migration of gas and groundwater migration from deeper CBM target formations to be comparable to shale gas as noted under the technical hydraulic fracturing stage above.

An important additional element to consider with CBM operations during production is the management of produced water. Unlike tight oil, tight gas and shale gas reservoirs where the hydrocarbons are trapped within rock, gas associated with CBM adsorbs to the surface of coal. It is necessary to create the correct pressure balance to enable desorption of the gas through pumping of groundwater from the target formation. This results in a significant quantity of produced waters for CBM (up to 65m^3 per day/per well (IEA, 2012)). The volume of traffic required to transport the volume of produced water to the point of treatment/discharge will therefore also be greater (unless pipelines are in place to transfer the produced water). The traffic burden and associated risks and impacts for CBM may be potentially more significant compared to shale gas. The abstraction of groundwater also presents a risk to water resources in overlying or lateral formations where a hydrogeological connection exists. Shale gas is found in less permeable formations, typically at greater depth and separated from fresh water resources by a large distance. There is, therefore a potentially more significant impact from CBM on water resources compared to shale gas during production due to its greater potential proximity to potable resources.

6. Well abandonment.

The final stage of the fracturing process is well abandonment and closure of the site. These are activities which will be similar across all of the UFF types discussed here. On this basis the identified risks and impacts for CBM are expected to be comparable to those of shale gas.

Table 3.1 Screening – Comparison of Other UFF and Shale Gas Risks and Impacts (per well basis)

Stage	Aspect	Tight gas	Tight oil	CBM
1. Well pad site identification and preparation	Groundwater contamination	Not applicable	Not applicable	Not applicable
	Surface water contamination risks	Comparable	Comparable	Comparable
	Water resource depletion	Not applicable	Not applicable	Not applicable
	Releases to air	Comparable	Comparable	Potentially less significant
	Land take	Comparable	Comparable	Not classifiable
	Biodiversity impacts	Not classifiable	Not classifiable	Not classifiable
	Noise	Comparable	Comparable	Comparable
	Visual impact	Comparable	Comparable	Not classifiable
	Seismicity	Not applicable	Not applicable	Not applicable
	Traffic	Comparable	Comparable	Potentially less significant
2. Well design, drilling, casing and cementing	Groundwater contamination	Comparable	Comparable	Comparable
	Surface water contamination risks	Comparable	Comparable	Comparable
	Water resource depletion	Not applicable	Not applicable	Not applicable
	Releases to air	Comparable	Comparable	Potentially less significant
	Land take	Not applicable	Not applicable	Not applicable
	Biodiversity impacts	Comparable	Comparable	Comparable
	Noise	Comparable	Comparable	Comparable

Stage	Aspect	Tight gas	Tight oil	CBM
	Visual impact	Comparable	Comparable	Comparable
	Seismicity	Not applicable	Not applicable	Not applicable
	Traffic	Comparable	Comparable	Potentially less significant
3. Technical hydraulic fracturing	Groundwater contamination	Comparable	Comparable	Potentially more significant*
	Surface water contamination risks	Comparable	Comparable	Comparable
	Water resource depletion	Potentially less significant	Potentially less significant	Potentially less significant
	Releases to air[1]	Comparable	Comparable	Potentially more significant
	Land take	Not applicable	Not applicable	Not applicable
	Biodiversity impacts	Comparable	Comparable	Comparable
	Noise	Comparable	Comparable	Comparable
	Visual impact	Comparable	Comparable	Comparable
	Seismicity	Comparable	Comparable	Comparable
	Traffic	Potentially less significant	Potentially less significant	Potentially less significant
4. Well completion	Groundwater contamination	Comparable	Comparable	Comparable
	Surface water contamination risks	Comparable	Comparable	Comparable
	Water resource depletion	Not applicable	Not applicable	Not applicable
	Releases to air	Comparable	Comparable	Comparable
	Land take	Not applicable	Not applicable	Not applicable
	Biodiversity impacts	Comparable	Comparable	Comparable

Stage	Aspect	Tight gas	Tight oil	CBM
	Noise	Not classifiable	Not classifiable	Not classifiable
	Visual impact	Not applicable	Not applicable	Not applicable
	Seismicity	Comparable	Comparable	Comparable
	Traffic	Potentially less significant	Potentially less significant	Potentially less significant
5. Production	Groundwater contamination	Comparable	Comparable	Potentially more significant*
	Surface water contamination risks	Comparable	Comparable	Comparable
	Water resource depletion	Potentially less significant	Potentially less significant	Potentially less significant
	Releases to air	Comparable	Comparable	Potentially more significant*
	Land take	Comparable	Comparable	Not classifiable
	Biodiversity impacts	Comparable	Comparable	Comparable
	Noise	Comparable	Comparable	Comparable
	Visual impact	Comparable	Comparable	Comparable
	Seismicity[2]	Comparable	Comparable	Comparable
	Traffic	Potentially less significant	Potentially more significant	Potentially more significant
6. Well / site abandonment	Groundwater contamination	Not classifiable	Not classifiable	Not classifiable
	Surface water contamination risks[3]	Not applicable	Not applicable	Not applicable
	Water resource depletion[4]	Not applicable	Not applicable	Not applicable
	Releases to air	Comparable	Comparable	Comparable
	Land take	Not classifiable	Not classifiable	Not classifiable

Stage	Aspect	Tight gas	Tight oil	CBM
	Biodiversity impacts	Not classifiable	Not classifiable	Not classifiable
	Noise[5]	Not applicable	Not applicable	Not applicable
	Visual impact	Not classifiable	Not classifiable	Not classifiable
	Seismicity	Not applicable	Not applicable	Not applicable
	Traffic	Not applicable	Not applicable	Not applicable

Notes:
Comparable: broadly comparable to the risks and impacts of shale gas
Potentially less significant: has the potential to be less significant than shale gas dependant on aspects such as scale and location specific factors. The term 'potentially less significant', does not mean that a risk is guaranteed to be smaller as, if the scale of operations is the same as for shale gas (which is possible), measures may be required to be the same/similar as the risk level may be comparable to that of shale gas.
Potentially more significant: has the potential to be more significant than shale gas dependant on aspects such as scale and location specific factors
Not applicable: aspects that are not relevant to the stage.
Not classifiable: aspects that are relevant but for which there is insufficient information to enable assessment. For further information see Section 2 of AEA (2012).
1 For CBM, potentially more significant releases to air refers to fugitive releases of methane due to likely shallower depth than shale gas and greater potential for methane emigration to the surface. For CBM aspects with an asterisk (*) the comparison may differ for shallow and deep target formations, refer to the screening results discussion for further information.
2 Refracturing may be needed in the production stage. In this case risks and impacts would be 'comparable' as per the 'technical hydraulic fracturing' stage.
3 Not applicable as no discharges to surface waters at this stage.
4 Not applicable as no water resource requirements at this stage.
5 Not applicable as no site production operations at this stage.

3.4 Stage Two: Risk Assessment and Evaluation

This section presents the findings of the risk assessment. Those aspects assessed as 'potentially less significant' or 'potentially more significant' from the stage one screening process are evaluated. While the nature and properties of tight oil and tight gas represent different technical issues in managing the product extracted, the processes of fracturing and extracting the material are the same. The nature of risks and impacts reviewed in the screening stage were generally similar to those of shale gas. As such, to avoid repetition the discussion for tight oil and tight gas is covered here jointly and differences indicated where relevant. This is followed by the discussion for CBM indicating aspects that may differ if target formations are shallow or deep.

3.4.1 Tight Gas and Tight Oil

Table 3.2 presents the risk assessment for tight gas and tight oil on those items carried forward from the screening stage. The general approach to, and technical options for, hydraulic fracturing for tight gas and oil are largely similar to those used in shale gas. Whilst different surface operations are required for tight oil due to the different physical nature of the hydrocarbon (e.g. storage, processing, handling, transportation), such operations are transferable from the conventional oil industry and will be addressed by existing conventional oil industry practice and regulations; the focus for this study is on the aspects specific to tight oil. No identified risks from stages 1, 2 or 6 (preparation, design and drilling and well abandonment respectively) were deemed to be non-comparable to shale gas operations and so the risk assessment and evaluation phase concentrated on stages 3-5 only (hydraulic fracturing, well completion and the production stage).

The key operational difference that influences associated risks between hydraulic fracturing for both tight gas and tight oil and hydraulic fracturing for shale gas are the quantities of water required for hydraulic fracturing. ICF (2013) suggests that tight gas uses between 200 and 7,100 m^3/well and tight oil between 5,700 and 25,600 m^3/well compared to 7,600 to 34,100 m^3/well for shale gas during fracturing (the variations partly influenced by formation depth and horizontal distance of the well, with the latter noted as being longer than for shale gas in the Bakken tight oil play). While these ranges have some overlap and the authors recognise that the actual volume required will be depth and formation specific, potentially the water demand requirements for tight oil and particularly tight gas may be lower. The AEA (2012) report for shale gas ranked the water depletion risk during fracturing as Moderate. With the application of BAU and likely to be applied measures as set out in AMEC (2014)[30] the risk rating is judged to be Low.

Impacts on air quality are possible due to the potential for greater vehicle movements associated with transporting of tight oil during the production stage (pipeline transportation is not assumed). Risks and impacts associated with traffic are potentially less significant for tight gas than for shale gas in both the well completion and production stages due to fewer vehicle movements related to water and flowback transportation. As noted above, traffic associated with produced water management for tight gas is assumed to have a similar range of activity as that for shale gas traffic (produced water generation being highly variable from UFF formations. Also noted above, for

[30] Refer to Appendix B for likely to be applied measures for water depletion.

tight oil, production stage traffic may be potentially more significant for tight oil than for shale gas due to vehicle movements associated with oil transportation.

Other aspects were evaluated as having broadly similar risk ratings as for shale gas.

3.4.2 Coalbed Methane

Table 3.3 presents a breakdown of the risk assessment for CBM on those items carried forward from the screening stage. The activities and risks associated with CBM will be different to those seen within tight oil, tight gas and shale gas, due to the nature of the geology and extraction process. A summary of key risks and issues is provided below:

- Stage 1. Preparation – The well pad size for CBM is expected to be smaller for CBM compared to shale gas (Dart Energy 2012); although the overall concession size could potentially be similar. The smaller well pad size has consequences when preparing ground for well development. This includes smaller equipment or the same size equipment (as shale gas operations) but for shorter durations. The reduced use of heavy machinery means that the risks regarding releases to air, visual impact and traffic will likely be lower than shale gas. However the activities within this stage are broadly similar across all UFF types including shale gas and therefore as a result the risk rating is deemed similar.

- Stage 2. Design, drilling, casing and cementing – As CBM operations generally work at shallower depths than shale gas, the required effort for drilling, casing and cementing will be reduced. This has a consequence for the size of the equipment required to carry out the drilling and associated air emissions. Equally the reduction in the quantity of materials required (such as casings) means the volume of traffic to and from site will be lower.

- Stage 3. Technical Hydraulic Fracturing – The more brittle nature of coal seams and shallower depth means that water demand for fracturing is likely to be lower compared to shale gas. This is turn means the equipment required to carry out the operation is smaller as will be the volume of traffic required to transport water to the site. Conversely the shallower depth and increased potential proximity to groundwater could potentially present increased risks to groundwater contamination. The AEA (2012) report for shale gas ranked groundwater contamination risk at this stage as High. With the application of specific measures as set out in AMEC (2014) the risk rating is judged to be moderate[31]. It is possible that groundwater contamination risks differ for shallow and deep wells (where the source of contamination is the target formation), with deep wells exhibiting lower risk due to the further geological barriers between groundwater resources and gas producing formations.

- Stage 4. Well completion – The reduction in water demand during the fracturing stage will also mean that there will be a reduction in the quantity of flowback compared to shale gas operations. This in turn means the volume of traffic required to transport the flowback created will be lower than seen in shale gas operations.

- Stage 5. Production – Similarly to the hydraulic fracturing stage the issue of water demand is key for this part of the process also. CBM production will likely use less water than shale gas operations at the same stage while shallower depths increase the risk to groundwater contamination from injected

[31] Refer to Appendix B for information on likely to be applied measures for groundwater.

fracture fluid. As with the hydraulic fracturing stage, it is possible that groundwater contamination risks differ for shallow and deep wells (where the source of contamination is the target formation), with deep wells exhibiting lower risk due to the further geological barriers between groundwater resources and gas producing formations.

The risk assessment process for CBM also identified new risks which are unique to CBM and were not covered in the AEA (2012) review of shale gas or the above assessment of tight gas or tight oil. Table 3.4 provides a breakdown of these risks which relate to the production stage of the process. The nature of CBM means that the gas is adsorbed to the surface of the coal and to promote a flow of gas excess water from the coal seam must be pumped out to lower pressure and allow gas to desorb. This leads to greater quantities of produced water than seen within shale gas, tight oil or tight gas. Furthermore where a negative pressure is created to allow gas to flow it can inadvertently draw away fresh water from groundwater sources into the coal seam where it can become contaminated.
The new risks identified are:

- Risks of surface water contamination from greater quantities of actively pumped produced water at the surface which must be managed and treated to the standard required by permits[32]. Increased volumes requiring more frequent transport, treatment and discharge may result in an increased risk of surface water contamination (e.g. through spillage during transfer, treatment plant failure);

- Risks of increased water resource depletion from groundwater supplies being drawn down towards the target formation; and

- Potential risk of methane seeping through geological strata and being released as fugitive emissions. This risk may increase compared to shale gas and tight gas due to the shallower depth and lack of barrier rock strata to prevent such gas reaching the surface.

Measures to address the risks identified in the following tables are discussed in Section 4.

[32] Produced water has variable quality (e.g. USEPA (2013) and Umweltbundesamt (2013)) indicate a range from 7 to 128,000 mg/l total dissolved solids in produced water from CBM formations.

Table 3.2 Risk Assessment of Screened Tight Oil (TO) and Tight Gas (TG) Aspects

Stage	Aspect	AEA risk rating (shale gas focus)	Amec Foster Wheeler risk rating after application of measures1 (shale gas focus)	TO and TG risks and impacts relative to shale gas	Risk assessment			
					Consequence	Frequency	Risk rating	Reasoning 1
3. Technical hydraulic fracturing	Water Resource Depletion	Moderate	Low	Potentially less significant	Minor	Rare	Low	Potentially less significant and likely will be less than shale gas due to lower water consumption. Application of 'likely to be applied' measures for shale gas is judged to reduce frequency from occasional to rare on the AEA risk matrix resulting in the risk rating reducing from Moderate to Low. TO and particularly TG have generally lower water consumption than shale gas potentially further reducing the potential risk. Risk rating including application of likely to be applied measures is judged to be Low.
	Traffic	Moderate	Moderate	Potentially less significant	Minor	Occasional	Moderate	Potentially less significant and likely will be less than shale gas due to likely fewer vehicle movements. Application of 'likely to be applied' measures for shale gas is unlikely to affect the level of activity and hence consequence and frequency. No change results in the AEA risk rating. TO and particularly TG have generally lower water consumption than shale gas potentially reducing traffic related aspects. Measures to mitigate risk for shale gas when applied to similar activities for TO and TG will have the same effect. Overall risk rating is judged to remain at Moderate.

Stage	Aspect	AEA risk rating (shale gas focus)	Amec Foster Wheeler risk rating after application of measures1 (shale gas focus)	TO and TG risks and impacts relative to shale gas	Risk assessment			
					Consequence	Frequency	Risk rating	Reasoning 1
4. Well completion	Traffic	Low	Low	Potentially less significant	Slight	Likely	Low	Potentially less significant and likely will be less than shale gas due to likely fewer vehicle movements. Application of 'likely to be applied' measures for shale gas is unlikely to affect the level of activity and hence consequence and frequency. No change results in the AEA risk rating. TO and particularly TG have generally lower water consumption and corresponding flowback than shale gas potentially reducing traffic related aspects. Measures to mitigate risk for shale gas when applied to similar activities for TO and TG will have the same effect. Overall risk rating is judged to remain at Moderate.
5. Production	Water Resource Depletion	Moderate	Low	Potentially less significant	Minor	Rare	Low	Potentially less significant and likely will be less than shale gas due to lower water consumption. Application of 'likely to be applied' measures for shale gas is judged to reduce frequency from occasional to rare on the AEA risk matrix resulting in the risk rating reducing from Moderate to Low. TO and particularly TG have generally lower water consumption than shale gas potentially further reducing the potential risk. Risk rating including application of likely to be applied measures is judged to be Low.

Stage	Aspect	AEA risk rating (shale gas focus)	Amec Foster Wheeler risk rating after application of measures1 (shale gas focus)	TO and TG risks and impacts relative to shale gas	Risk assessment			
					Consequence	Frequency	Risk rating	Reasoning 1
	Traffic (TG only)	Low	Low	Potentially less significant	Slight	Likely	Low	TG only Potentially less significant and likely will be less than shale gas due to likely fewer vehicle movements. Application of 'likely to be applied' measures for shale gas is unlikely to affect the level of activity and hence consequence and frequency. No change results in the AEA risk rating. Produced water volume generation rate is formation specific and so assumed to be in a similar range to that for shale gas, hence associated traffic is assumed to be comparable; however, TG has generally lower water consumption and corresponding flowback than shale gas associated with the fracturing which potentially reduces traffic related aspects overall. Measures to mitigate risk for shale gas when applied to similar activities for TG will have the same effect. Overall risk rating is judged to remain at Low.

Stage	Aspect	AEA risk rating (shale gas focus)	Amec Foster Wheeler risk rating after application of measures1 (shale gas focus)	TO and TG risks and impacts relative to shale gas	Risk assessment			
					Consequence	Frequency	Risk rating	Reasoning 1
	Traffic (TO only)	Low	Low	Potentially more significant	Slight	Highly likely	Moderate	TO only Potentially more significant and likely will be more than shale gas due to vehicle movements associated with transport of oil (pipelines not assumed). Application of 'likely to be applied' measures for shale gas is unlikely to affect the level of activity and hence consequence and frequency. No change results in the AEA risk rating. Whilst TO has generally lower water consumption and corresponding flowback than shale gas potentially reducing traffic related aspects, additional vehicle movements are associated with transporting TO. Measures to mitigate risk for shale gas when applied to similar activities for TO will have the same effect. Overall risk rating is judged to remain at Moderate.

1. For measures see Appendix B.

Table 3.3 Risk Assessment of Screened CBM Aspects

Stage	Aspect	AEA risk rating (shale gas focus)	Amec Foster Wheeler risk rating after application of measures[1] (shale gas focus)	CBM risks and impacts relative to shale gas	Risk assessment			
					Consequence	Frequency	Risk rating	Reasoning
1. Well pad site identification and preparation	Releases to air	Low	Low	Potentially less significant	Slight	Likely	Low	Potentially less significant and likely will be less than shale gas due to likely smaller scale operations. Application of 'likely to be applied' measures for shale gas is unlikely to affect the level of activity and hence consequence and frequency. No change results in the AEA risk rating. In comparison to shale gas operations, the preparation of and excavation of land for CBM will likely either utilise smaller equipment or the same equipment for a shorter time period. This may reduce the effects of releases to air from heavy machinery. However this reduction in scale is not expected to be sufficient to reduce the overall risk for this activity compared to similar activities within shale gas. Therefore the risk level is judged to remain the same.
	Land take	Moderate	Moderate	Not classifiable	Minor	Likely	Moderate	The land take issue for CBM is not clear. Existing work at Falkirk (Scotland) has significantly smaller land take demand with 0.4 hectares per pad compared to shale gas which can be up to 2.24 hectares per pad (AMEC (2014)). However it is possible depending on the well configuration and geological resource that concessions could potentially be at the same scale as shale gas operations. Therefore overall risk rating is judged to match that for shale gas in lieu of further evidence.
	Visual impact	Low	Low	Not classifiable	Slight	Likely	Low	Judgement is Low risk rating.

Stage	Aspect	AEA risk rating (shale gas focus)	Amec Foster Wheeler risk rating after application of measures[1] (shale gas focus)	CBM risks and impacts relative to shale gas	Risk assessment			
					Consequence	Frequency	Risk rating	Reasoning
	Traffic	Low	Low	Potentially less significant	Slight	Likely	Low	Potentially less significant and likely will be less than shale gas due to likely fewer vehicle movements. Application of 'likely to be applied' measures for shale gas is unlikely to affect the level of activity and hence consequence and frequency. No change results in the AEA risk rating. The smaller scale of the operation and equipment required means that the burden on traffic will be potentially less significant than for shale gas operations. This may potentially reduce impacts from traffic but not negate them. Risk rating is judged Low.
2. Well design, drilling, casing and cementing	Releases to air	Moderate	Moderate	Potentially less significant	Minor	Occasional	Moderate	Potentially less significant and likely will be less than shale gas due to likely smaller scale operations. Application of 'likely to be applied' measures for shale gas is unlikely to affect the level of activity and hence impacts consequence and frequency. No change results in the AEA risk rating. Shorter drilling period and smaller equipment will mean the potential risks and impacts for releases to air would be potentially less significant than seen in shale gas, however it is unclear whether this difference is significant enough to impact the overall risk rating. Risk rating is judged Moderate.
	Traffic	Low	Low	Potentially less significant	Slight	Likely	Low	Potentially less significant and likely will be less than shale gas due to likely fewer vehicle movements. Application of 'likely to be applied' measures for shale gas is unlikely to affect the level of activity and

Stage	Aspect	AEA risk rating (shale gas focus)	Amec Foster Wheeler risk rating after application of measures[1] (shale gas focus)	CBM risks and impacts relative to shale gas	Risk assessment			
					Consequence	Frequency	Risk rating	Reasoning
								hence impacts consequence and frequency. No change results in the AEA risk rating. Reduced need for materials and equipment compared to shale could reduce the volume of traffic and result in a potentially less significant risk. Risk rating is Low and comparable to shale gas.
3. Technical hydraulic fracturing	Groundwater contamination	High	Moderate	Potentially more significant	Moderate	Rare	Moderate	Application of 'likely to be applied' measures for shale gas is judged to reduce frequency from occasional to rare on the AEA risk matrix resulting in the risk rating reducing from High to Moderate. Potentially more significant due to greater proximity to drinking water aquifers due to shallower depth of the target formation could result in risks being potentially more significant due to the hazard of formation fluids and gas migrating through pathways in the coal seam. However, application of the likely to be applied measures assumed for shale gas (see footnote 31) is judged to mitigate this risk. For CBM, risk rating is therefore judged to be Moderate. For CBM target formations at greater depth (e.g. >1,500m) it is possible that likelihood will reduce to Extremely Rare due the depth and further geological barriers between groundwater resources and the gas producing formation. In this case, for deeper formations, risk rating may reduce to Low.
	Water resource depletion	Moderate	Low	Potentially less significant	Minor	Rare	Low	Potentially less significant and likely will be less than shale gas due to lower water consumption. Application of 'likely to be applied' measures for shale gas is judged to reduce frequency from

Stage	Aspect	AEA risk rating (shale gas focus)	Amec Foster Wheeler risk rating after application of measures[1] (shale gas focus)	CBM risks and impacts relative to shale gas	Risk assessment			
					Consequence	Frequency	Risk rating	Reasoning
								occasional to rare on the AEA risk matrix resulting in the risk rating reducing from Moderate to Low. CBM has lower water consumption than shale gas potentially reducing the potential risk. Risk rating including application of likely to be applied measures is judged to be Low
	Releases to air	Low	Low	Potentially more significant	Slight	Likely	Low	Potentially more significant due to potential for fugitive releases reflecting typically shallower depth of fracturing and a potential for more significant risk of fugitive gas seepage through rock strata. Potentially offset by comparatively smaller scale operations than shale gas, hence the equipment used during fracturing for CBM will likely either utilise smaller equipment or the same equipment for a shorter time period. However this reduction in scale is not expected to be sufficient to reduce the overall risk for this activity compared to similar activities within shale gas. Application of 'likely to be applied' measures for shale gas is unlikely change overall risks characteristics significantly. No change results in the AEA risk rating. The risk rating is judged to be Low.
	Traffic	Moderate	Moderate	Potentially less significant	Minor	Occasional	Moderate	Potentially less significant and likely will be less than shale gas due to likely fewer vehicle movements associated with lower flowback volume. Application of 'likely to be applied' measures for shale gas is unlikely to affect the level of activity and

Stage	Aspect	AEA risk rating (shale gas focus)	Amec Foster Wheeler risk rating after application of measures[1] (shale gas focus)	CBM risks and impacts relative to shale gas	Risk assessment			
					Consequence	Frequency	Risk rating	Reasoning
								hence consequence and frequency. No change results in the AEA risk rating. CBM has potentially less water consumption and linked traffic movements than shale gas. Measures identified to mitigate risk for shale gas when applied to similar activities for CBM will have the same level of effect. On this basis the measures identified will not further reduce risk for CBM. The risk rating is judged to be Moderate.
4. Well completion	Traffic	Low	Low	Potentially less significant	Slight	Likely	Low	Potentially less significant and likely will be less than shale gas due to likely fewer vehicle movements. Application of 'likely to be applied' measures for shale gas is unlikely to affect the level of activity and hence consequence and frequency. No change results in the AEA risk rating. CBM has lower potential for flowback volumes requiring transportation linked to lower water consumption. Measures identified to mitigate risk for shale gas when applied to similar activities for CBM will have the same level of effect. On this basis the measures identified will not further reduce risk for CBM. The risk rating is judged to be Low.
5. Production	Groundwater contamination	High	Moderate	Potentially more significant	Moderate	Rare	Moderate	Application of 'likely to be applied' measures for shale gas is judged to reduce frequency from occasional to rare on the AEA risk matrix resulting in the risk rating reducing from High to Moderate. Potentially more significant due greater proximity to drinking water aquifers due to shallower depth of the target formation could result in risks being potentially

Stage	Aspect	AEA risk rating (shale gas focus)	Amec Foster Wheeler risk rating after application of measures[1] (shale gas focus)	CBM risks and impacts relative to shale gas	Risk assessment			
					Consequence	Frequency	Risk rating	Reasoning
								more significant due to the hazard of formation fluids and gas migrating through pathways in the coal seam. Application of the likely to be applied measures assumed for shale gas (see footnote 31) is judged to mitigate this risk. For CBM, risk rating is therefore judged to be Moderate. For CBM target formations at greater depth (e.g. >1,500m) it is possible that likelihood will reduce to Extremely Rare due the depth and further geological barriers between groundwater resources and the gas producing formation. In this case, for deeper formations, risk rating may reduce to Low.
	Water resource depletion	Moderate	Low	Potentially less significant	Minor	Rare	Low	Potentially less significant and likely will be less than shale gas due to lower water consumption. Application of 'likely to be applied' measures for shale gas is judged to reduce frequency from occasional to rare on the AEA risk matrix resulting in the risk rating reducing from Moderate to Low. CBM has lower water consumption than shale gas potentially further reducing the potential risk. Risk rating including application of likely to be applied measures is judged to be Low.
	Land take	Moderate	Moderate	Not classifiable	Minor	Likely	Moderate	The land take issue for CBM is not clear. Existing work at Falkirk (Scotland) has significantly smaller land take demand with 0.4 hectares per pad compared to shale gas which can be up to 2.24 hectares per pad (AMEC (2014)). However it is possible depending on the well configuration and geological resource that concessions could potentially be at the same scale as shale gas

Stage	Aspect	AEA risk rating (shale gas focus)	Amec Foster Wheeler risk rating after application of measures[1] (shale gas focus)	CBM risks and impacts relative to shale gas	Risk assessment			
					Consequence	Frequency	Risk rating	Reasoning
								operations. Therefore overall risk rating is judged to match that for shale gas in lieu of further evidence.
	Traffic	Low	Low	Potentially more significant	Slight	Likely	Low	Potentially more significant due to higher volumes of produced water requiring management and potentially movement by road. Application of 'likely to be applied' measures for shale gas is unlikely to affect the level of activity and hence consequence and frequency. No change results in the AEA risk rating. Measures identified to mitigate risk for shale gas when applied to similar activities for CBM will have the same level of effect. On this basis the measures identified will not further reduce risk for CBM. The risk rating is judged to be Low.

1. For measures see Appendix B.

Table 3.4 Risk Assessment of Further Risks for CBM

Stage	Aspect	Risk assessment			
		Consequence	Frequency	Risk rating	Reasoning
5. Production	Groundwater contamination	No data	No data	Low[1]	CBM operates at shallower depths than shale gas hence there is potentially an increased risk of impacts on near-surface groundwater resources and quality, particularly linked to groundwater pumping required in CBM production. Incidences arising from CBM operations are not well documented and therefore it is difficult to predict the frequency and magnitude, but overall risk is expected to be low (due to minor consequence and rare occurrence). This risk would reduce for deeper CBM target formations due to increased distance from near surface groundwater resources.
	Releases to air	No data	No data	Low[1]	As CBM operations work at shallower depths than shale gas there is potentially a greater risk of gas seepage through rock strata and being emitted as fugitive emissions. The prevalence of this phenomenon from CBM operations is not well documented and therefore it is difficult to predict the frequency and magnitude, but overall risk is expected to be low (due to minor consequence and rare occurrence). This risk would reduce for deeper CBM target formations due to increased distance from near surface groundwater resources.
	Surface water contamination	Minor	Occasional	Moderate	Greater volumes of produced water from CBM operations (compared to shale gas) mean that careful management and handling is required. Potentially greater volumes of wastewater would present a tangible risk for spillages/releases resulting in surface water contamination.
	Water resource depletion	Minor	Occasional	Moderate	Unlike other types of UFF, gas is adsorbed to the surface of coal structures and is released for flow into the well by pumping water from the well and reducing pressure. This operation potentially presents a risk that during pumping a negative pressure gradient can draw fresh water away from overlying groundwater. Therefore pumping operations for CBM could potentially adversely affect water resources during pumping.

1. Risk rating classified as low on the basis of expert judgement (due to probable minor consequence and rare occurrence), in the absence of referenced information.

4. Measures

4.1 Introduction

This section provides an assessment of whether the measures identified for shale gas are appropriate and proportionate to the risks and impacts for other UFF where these have been identified as not comparable in Section 3. For risks and impacts that are concluded to be comparable, it is assumed that the measures appropriate for shale gas will also be appropriate for the other UFF (and so these are not considered here).

Before the assessment of the measures, a summary of the approach to measure development is presented.

4.2 Development of Measures

The approach to development of measures is described in detail in AMEC (2014). A brief summary of the approach is provided here.

Measure Development

Measures to address risks and their impacts were developed based on: (a) the analyses of key risks and mitigation measures, (b) an analysis of the *acquis communautaire* and whether it requires the identified measures to be implemented; and (c) subsequent discussion with the Commission and peer review. The measures were organised to identify the following aspects:

- Whether the measure is business as usual (BAU) or non-BAU;
- Project stage: stage(s) of the unconventional gas extraction process that the measure would be applied to;
- Level of ambition: potential to reduce both the likelihood of the risks being addressed and the consequences; and
- Grouping according to a number of different themes agreed with the Commission.

This allowed comparison of similar and alternative measures e.g. more or less prescriptive approaches to addressing risks, or higher/lower levels of ambition.

Business as Usual vs. Non-Business as Usual

Those measures identified as already required by EU legislation were classified as BAU. If measures only *may* be required (i.e. there is uncertainty), then they were classified as non-BAU. However, many 'non-BAU' measures (i.e. not definitely required by EU legislation) might be normal practice by the industry. To address this, non-BAU measures that were *likely* to be applied by industry regardless of legislative requirements were considered. The degree of uptake of the measures by operators was then considered and (assumed, illustrative) uptake rates were integrated into the analysis[33]. This enabled the costs of those 'non-BAU' measures that were likely to be applied by industry as a result of normal practice to be taken into account in analysis of policy options.

The following are significant activities for UFF that are BAU under the existing EU *acquis* and hence additional measures to address risks and impacts are not considered further:

- Drilling mud waste management and disposal: regulation of drilling mud waste is addressed through the existing legislation (Mining Waste Directive). Whilst drilling mud composition and contamination may vary, the requirement to meet waste management and disposal regulatory requirements is already established. Furthermore, management practices, and treatment and disposal methods are already established in the oil and gas industry.

- Wastewater treatment and discharge: requirements for wastewater treatment and discharge are established through implementation of existing legislation (e.g. Mining Waste Directive, Water Framework Directive). Whilst wastewater compositions may differ (e.g. levels of salinity, mineral oil, metals, NORM), the requirement to treat wastewater and requirements on discharges are part of existing legislation. Treated wastewater risks and impacts would be comparable to those for shale gas and CFF as the same discharge requirements would apply. A best available techniques reference document (BREF) is currently being reviewed and should encompass the management of waste from oil and gas activities.

Level of Ambition

Level of ambition of the measures was determined by considering two aspects: (1) potential to reduce the likelihood of the identified risks being realised and (2) potential to reduce the magnitude/consequence of damage. For each aspect, the team assigned three levels of ambition: High (H), Medium (M) and Low (L).

With regard to potential to reduce likelihood, H referred to likelihood reduced to zero or a negligible level, M referred to significant reduction in likelihood but still potentially foreseeable and L referred low to moderate reduction in likelihood. With regard to damage/consequence reduction, H referred to damage reduced to negligible level (no ascertainable damage to health/environment/property), M referred to damage reduced to a broadly acceptable level (e.g. compliance with expected standards in other fields) and L referred to low to moderate reduction in (potential) damage. Level of ambition of each measure was then assigned by combining the different level of ambition from these two aspects (e.g. HH, ML, etc.).

[33] Measures considered *likely to be applied* had a 90% uptake level and measures considered *possible to be applied* had 40% uptake level. For complete list see section 3 and Table E2 in Appendix E of AMEC (2014).

Grouping by Theme

Measures were grouped into the following themes:

- Zoning;
- Underground;
- Chemicals usage;
- Water depletion;
- Surface water quality;
- Air quality;
- Waste;
- Post-closure;
- Public acceptance; and
- Other measures (not falling into the above).

The aim of grouping by theme (and categorisation by relevant process stage) was to create coherent groups of measures and to identify at which stage of the process each measure may apply. This allowed comparison between similar or alternative measures as well as understanding possible risks they may be addressed at any stage. The approach also allowed comparison between measures at differing levels of ambition.

Measures within each theme were presented describing:

- Risks of concern within the theme;
- Overview of possible measures – the characteristics, costs, description of measure combinations (complementary/redundancy), comparative levels of ambition;
- Economic impacts – compliance and administrative costs;
- Environmental benefits; and
- Social impacts.

4.3 Review of Measures

4.3.1 Approach

For the risks that were found to be not comparable to shale gas, a review of the 'appropriateness' and 'proportionality' of the measures has been carried out taking account of information presented in Section 3.

For these risks, the approach considered the measures identified for shale gas in the context of the other UFF for their appropriateness, i.e., whether or not the measure is suitable to address the risk for that form of UFF. Proportionality was then judged as being 'over-specified', 'proportionate' or 'under-specified'. Further measures were also developed to address risks that were found to be additional for the other UFFs when compared to shale gas.

4.3.2 Outcome of the Review of Existing Measures

Measures (see Appendix B) were assessed for the following types of impacts:

- Water resource depletion measures: for tight oil, tight gas and CBM;
- Traffic: for tight oil, tight gas and CBM;
- Releases to air: for tight oil and CBM;
- Land take: for CBM;
- Visual impact: for CBM; and
- Groundwater contamination risks: for CBM.

Water Resource Depletion Measures

- All measure are judged appropriate for tight oil, tight gas and CBM;
- All measures are judged proportionate for tight oil and tight gas;
- The following measures are judged to be over-specified for CBM due to lower water demand requirements for CBM:
  3a vi Site baseline, establish water source availability and test for suitability[34]
  3b vi Monitoring, water resources availability
  3b ix Monitoring, water volumes and origin
  38b Demand profile for water
  N49 Strategic planning and staged approach of play development to avoid peaks in water demand

[34] Establishment of baseline for water source availability and tests for suitability only. Baseline establishment for other parameters (e.g. surface water and groundwater quality) remain relevant.

Traffic Measures

- All measure are judged appropriate for tight oil, tight gas and CBM;

- A number of measures are judged to be over-specified for tight oil, tight gas and CBM due to fewer vehicle movements associated with water and flowback management but may not necessarily be overspecified for the management of produced water, for example:
  60a Use of temporary surface pipes for distribution of water supply
  60b Use of temporary surface pipes for collection of flowback
  60c Site selection close to water sources to minimise haulage requirements
  61c Site selection close to flowback treatment/disposal facilities to minimise haulage requirements (judged over-specified for tight oil and tight gas only. Judged proportionate for CBM due to high volume of pumped groundwater during the production stage)

Releases to Air

- Assessed for CBM due to potentially smaller scale activities and pad size and also shallower wells resulting in shorter duration of diesel powered mobile plant and drilling rigs required;

- Measures are judged to be both appropriate and proportionate for tight oil and CBM.

Land take

- Assessed for CBM only and related to potentially smaller scale activities and pad size;

- Relevant measures relate to optimisation (e.g. pad spacing, density), cumulative effects and undertaking Strategic Environment Assessment. The measures are judged appropriate and proportionate for CBM.

Visual Impact

- Assessed for CBM only and related to potentially smaller scale activities and pad size;

- Relevant measures relate to the requirement for Environment Impact Assessment, including an assessment of cumulative impacts. The measures are judged to be appropriate and proportionate for CBM.

Groundwater Contamination

- Assessed for CBM only and related to potentially more significant risks and impacts arising from the shallower depths of formations, potential increased proximity to potable water resources and a potential for affecting overlying groundwater resources due to the need for groundwater pumping in the target formation;

- Measures are judged to be both appropriate and proportionate for CBM.

4.3.3 Assessment of Potential Additional Measure Requirements

Further risks were identified for CBM (see Table 3.4) related to the production stage. Observations and assessment of the requirement for additional measures are provided below regarding these risks. In reviewing potential additional risk mitigation measures, the measures presented in recent studies on CBM by BRGM (2013) and the Environment Agency (for England) (2014b) were examined.

Releases to Air

As CBM operations are typically at shallower depths than shale gas there is potential for an increased risk of gas seepage through rock strata (due to the lack of geological barriers) and being emitted as fugitive emissions. The prevalence of this phenomenon from CBM operations is not well documented and therefore it is difficult to predict the frequency and magnitude hence risk is rated 'Not classifiable' but overall risk would be expected to be Low.

Assessment: measures addressing groundwater contamination include measures aimed at developing conceptual models, searching for and documenting potential leakage pathways, modelling fracture programmes and both baseline and ongoing monitoring of methane in groundwater. Measures identified for shale gas (in AMEC, 2014) are likely to be adequate to also manage this risk.

Surface Water Contamination

CBM generates greater volumes of produced water than shale gas, tight oil and tight gas. Levels of salinity vary greatly depending on the formation (ranging from 1-128,000 mg/l chloride). Consequently, careful management and handling is required. The greater volumes may present a greater risk of spillage and release resulting in surface water contamination. Risk has been assessed as Moderate.[35]

Assessment: existing measures identified for shale gas (in AMEC, 2014) are likely to be adequate to manage the risk of surface water contamination, for example, existing measures include: good site practice to prevent of leaks and spills, undertaking sampling of surface water bodies in wet and dry periods (baseline and ongoing), construction of a berm around the site boundary, the use of tank level alarms and double-skinned closed storage tanks and installation of an impervious site liner under the well pad with puncture proof underlay.

Groundwater Contamination and Water Resource Depletion

CBM requires groundwater pumping. This operation potentially presents a risk that during pumping a negative pressure gradient can draw fresh water away from overlying potable groundwater resources resulting in potential risks and impacts to groundwater resources and quality (i.e. contamination).

Assessment: whilst existing measures (focussed on addressing groundwater contamination risks) include aspects such as modelling groundwater flows, additional measures are considered necessary. These measures are proposed to be developed through higher ambition variants of existing measures, in particular:

[35] Note treatment of wastewater to prevent surface water contamination is BAU. Refer to Section 4.2 for further discussion.

- 26d development of conceptual model. The shale gas measure focused on establishing the hydrogeological aspects prior to drilling. A further HIGH ambition option of the measure was included that extends work to model the impact of groundwater pumping on linked groundwater and surface water flows and quality;

- 3b vi monitoring and reporting of water resources availability. The shale gas measure focuses on water resource availability for operations. A further HIGH ambition option of the measure was included to enable extension of monitoring and reporting to include active groundwater resource / level management of the concession area; and

- 38a notification of water demand from fracturing operations to relevant water utilities and competent authorities. The shale gas measure focussed on the provision of information on water demand from fracturing and did not focus on actively managing the impact arising from the pumping of groundwater from areas also used as groundwater resources as may be required for CBM. A further HIGH ambition option for 38a was included to address this additional requirement.

5. Policy Options Assessment

5.1 Introduction

This section builds on the AMEC (2014) report and this report as a whole should be read in conjunction with the AMEC (2014) report. This section presents a summary of the approach used to assess the impacts of different policy options, noting variations to the AMEC (2014) approach. Policy options are summarised, AMEC (2014) provides a fuller discussion of the policy options characteristics.

5.2 Approach

5.2.1 Illustrative Concessions

Consistent with AMEC (2014), the concept of an 'illustrative gas concession' has been used as a basis upon which to assess potential costs and benefits. This approach has been used due to the uncertainties around the scale of future unconventional gas extraction in the EU and how this would develop over time. This allows the potential impacts to be assessed without the need for a mature industry to be developed. Clearly future developments may vary substantially in size and the related impacts would therefore vary significantly.

The illustrative concessions are based on a number of variables such as a typical assumed number of well pads per concession and wells per pad, water consumption, on-site power requirements, vehicle movements, etc. The illustrative concessions include not only technical aspects (i.e. number of pads/wells) but also the types and scale of parameters that are directly related to environmental impacts (e.g. volume of wastewater produced). The illustrative concessions information is presented in Appendix A and this has been used to inform the derivation of quantitative estimates of the impacts of measures. It should be noted that due to the degree of uncertainty in the selection of the reference values, the illustrative concession data are intended for demonstration purposes and parameters will vary significantly depending on site specific characteristics of specific projects.

The general framework of parameters developed for shale gas formed a starting point for the other UFF; however certain parameter values differ. The study has collated information focussing on the European situation wherever possible. This includes integrating responses to a questionnaire forwarded to Member States requesting the provision of information regarding tight gas, tight oil and CBM. Responses were received from Denmark, Germany, Portugal, Romania and the UK. The UK provided data for a limited number of parameters for exploratory CBM operations and Germany provided data for parameters regarding tight gas operations (the other responding Member States indicated that there are currently no relevant operations in their respective territories).

5.2.2 Assessment of Measure Impacts

The economic, environmental and social impacts of full implementation of each measure are considered (treated individually, not in a group) in AMEC (2014) and are not repeated here. In summary, for economic impacts, both compliance costs and administrative costs (for operators and authorities) were considered. Where there was a sufficient level of information, these economic impacts were quantitatively estimated, with assumptions drawn from existing literature and inputs from Amec Foster Wheeler experts. The experts included those with practical experience of large scale UFF projects in North America and Australia, as well as experience of implementing conventional hydrocarbon specific measures in the EU (e.g. surface water modelling, environmental impact assessment). When drawing from practical experience of UFF projects from outside Europe, the project team took into consideration the EU context in estimating the costs by using EU-specific assumptions such as the hourly wage for operators and external consultancy. Furthermore, the project team used a set of assumptions in an 'illustrative concession' (see Section 5.2.1), which provided a unit in describing the potential scale of unconventional gas development in the EU. Where there was an insufficient level of quantitative information or levels of uncertainty were too high, the impacts were discussed qualitatively.

5.3 Selected Policy Options

5.3.1 Introduction

This section presents a description and comparison of four selected policy options based on the initial analysis set out in Section 4 of AMEC (2014). The four options were:

- Option A: to take forward guidance and a recommendation under existing legislation, voluntary industry agreement and best practice;
- Option B: to amend several existing EU laws and accompany this with guidance;
- Option C: to adopt a new dedicated legal instrument in the form of a directive (setting overall goals/principles) and accompany this with guidance; and
- Option D: to adopt a new dedicated legal instrument in the form of a regulation, to set specific detailed obligations and accompany this with guidance.[36]

It should be noted that since the AMEC (2014) work focussed on shale gas, the Commission has partially taken forward Option A with the adoption of Recommendation 2014/70/EU in January 2014. This section begins with a brief description of each of the policy options summarised from AMEC (2014). It then compares these options in terms of the measures that are expected to be implemented under each, and a comparative analysis in relation to the costs of the options is subsequently presented. This is presented for tight gas, tight oil and CBM.

[36] In practice, Option D could also be implemented through a directive with more specific obligations than those included under Option C.

5.3.2 Policy Option A: Guidance and Recommendation

Option A is to take forward a recommendation, voluntary industry agreements and best practice plus guidance in relation to existing legislation. This option is for the Commission, working with stakeholders where relevant, to support the protection of health and the environment through the full range of non-legislative approaches available.

Interpretative guidance is the formal production of non-binding material setting out best practice in the application of specific aspects of EU legislation. A recommendation to Member States may be used to complement existing EU legislation. Such a recommendation provides non-binding actions with no obligatory power that may provide preparation for legislation in Member States (if deemed necessary by the latter). With regard to shale gas, AMEC (2014) identified a wide range of issues arising in the interpretation and application of individual Directives that could be elaborated through guidance. Such material would reduce uncertainty for operators and provide assistance to regulators who may be uncertain whether they are correctly implementing EU law in this evolving area. The issues apply also to other UFF. Guidance can examine specific issues with respect to different types of UFF in a flexible way. Further, it can readily be adapted as different UFF sources are developed, as best practice evolves and as environmental interactions are better understood. It is however to be noted that it is the European Court of Justice which is ultimately responsible for providing an authoritative interpretation of EU law.

Non-legislative approaches can be taken further with the development of voluntary approaches with industry and sharing of best practice. The opportunities and limitations of these approaches are explored in Section 4 of AMEC (2014).

5.3.3 Policy Option B: Amendment to the Acquis plus Guidance

Option B is to amend several existing EU laws and accompany this with guidance.

The basis for addressing the regulatory gaps in the existing *acquis* by amending the existing legislation are described in Section 4.5 of AMEC (2014) in which it was noted that the nature of the potential amendments would vary significantly. In some cases such amendments would be relatively minor, ensuring that a particular aspect of the operation of an unconventional gas facility or a specific activity is included in the scope of a Directive. In other cases the amendment could be significant aiming to encompass much of the operation or the facility. Option B would further support the implementation of the existing legislation through the adoption of guidance, voluntary agreements and sharing of best practice (i.e. Option A). Examples of possible amendments to the existing *acquis* which could be used to address gaps in the regulation of unconventional gas facilities are provided in the following table (from AMEC (2014).

Table 5.1 Examples of Possible Amendments to the Existing *Acquis* to Address Gaps in the Regulation of Unconventional Gas

Existing EU Instrument	Possible Amendments
EIA Directive	Clarity on the scope of application of EIA particularly for exploration stage.
Water Framework Directive (and daughter Groundwater Directive)	Clarity on the obligations with regard to protection of groundwater (quantity and quality). The GWD might require additional EQS to be included in the Annex.
Environmental Liability Directive	Amendment might be possible to include unconventional gas extraction as a category. However, this would depend on other amendments, e.g. if IED is amended to fully include unconventional gas extraction, the existing reference to IED in ELD would probably be sufficient.
Seveso III	To clarify inclusion of unconventional gas extraction activities, including exploration stage – it is unlikely a new instrument would include the full range of accident prevention and management requirements.
IED	IED could be amended to ensure full capture (or at least partial additional capture) of unconventional gas exploration and production in its scope.

The above amendments would all need to be taken forward fully to address unconventional gas extraction. Each contributes to improving regulatory capture in particular ways and, in some cases (e.g. ELD and Seveso), increases intra-*acquis* coherence. The most potentially far-reaching amendment would be that to IED.

The development of guidance, would be on the same basis as Option A, except that the amendment of existing legislation might require additional guidance to be developed and best practice to be shared on additional elements adopted in the amended legislation. Furthermore, amendment of the Industrial Emission Directive (IED) and Mining Waste Directive (MWD) would potentially require the adoption of new BREFs (or strengthening of existing ones), which would have the character of guidance, but which also have a legal standing in the implementation of those Directives. This option can readily take account of any specificities concerning UFF alongside those for shale gas.

Option B can, therefore, encompass all of the issues for which guidance and sharing best practice could be addressed within Option A, as well as filling some of the identified regulatory gaps through legal amendment and supporting these new obligations with additional (or expanded) guidance providing more assured uptake of measures to address the risks.

5.3.4 Policy Option C: Dedicated Directive plus Guidance

Option C is to adopt a new dedicated legal instrument in the form of a directive (setting over-arching goals/principles) and accompany this with guidance.

The basis and potential scope of a new dedicated instrument is described in Section 4.6 of AMEC (2014), and is not repeated here. The scope of such an instrument would be able to be wider than that of amending the existing *acquis* as covered in Option B. In principle, all issues associated with the exploration and production of UFF could be included.

Furthermore, such an instrument could be supported with the adoption of guidance, voluntary agreements and sharing of best practice where appropriate. Such guidance could be dedicated to helping regulators and operators interpret and implement the new instrument. Where aspects of the existing *acquis* remain appropriate (this would depend on the scope of a new instrument), guidance can be developed to help interpret this (as with Option A) and/or explore the interaction between that aspect of the existing *acquis* and the new instrument.

Option C, therefore, encompasses all of the issues for which guidance and sharing of best practice could be addressed within Option A, as well as addressing all of the regulatory gaps encompassed by Option B, as well as addressing further regulatory gaps that amendment of the existing *acquis* might not be able to address.

5.3.5 Policy Option D: Dedicated Regulation plus Guidance

Option D is a step further than Option C in that it also involves a dedicated new legal instrument, but in this case setting more specific and detailed obligations. In this report, it was assumed that this would be in the form of a regulation (so 'regulation' is referred to below), but such an instrument could equally be achieved through a more prescriptive directive.

As a regulation is directly applicable, its provisions need to be clear and precise as to what is required by whom. If there are provisions which are too vague or general, it is likely that these would require interpretation in law at national level and the benefit of directly applicable law would be lost.

This approach could specify precisely the actions required of operators during exploration and production. It could also include general objectives for operators to follow if these are clearly established in law and potentially linked to wider processes. For example, a requirement to apply BAT is clear and reference to dedicated BREFs would also be appropriate in a regulation.

5.3.6 Comparison of the Options

A comparison of the Options for shale gas is presented in Section 4.8.6 of AMEC (2014) where a discussion of efficiency, effectiveness and coherence is provided. The general nature of the options under consideration for other UFF is the same (albeit with adjustments to the precise measures applied under the options; see below for details of measure adjustments) and hence a general comparison of the options is not repeated here. The principal points of comparison of the options presented here is the range of measures that could be addressed by each option (cost issues are addressed in subsequent sections).

The measures that have been determined as appropriate to address the range of environmental and health risks associated with unconventional gas extraction under each of the policy options are presented in Appendix D for each other UFF (where for each of the four policy options, the table highlights those measures that would be potentially addressed by that option for each other UFF). All four options can take forward many measures for the other UFF as summarised in the following table (including shale gas for information from AMEC (2014).

Table 5.2 Number of Measures in Options

Option	Shale Gas	Tight Gas	Tight Oil	CBM
A	160	158	158	159
B	172	170	170	171
C	196	193	193	194
D	196	193	193	194

The initial comparison of the options is the division between legislative and non-legislative options, i.e. Option A compared to Options B, C and D. It is generally assumed that binding legislation will be more effective across the EU as a whole than non-binding instruments. Note that Option D does not address further measures than are possible through option C, but sets measures in a different legal context of a regulation.

The changes in measures selected under the options due to differences in risk and the appropriateness and proportionality of measures, when compared to the measures selected for shale gas (see AMEC (2014)), can be summarised as follows (see Section 4.3 for further discussion):

- Tight gas and tight oil. The following measures were not selected for any policy options:
  - 60c Site selection close to water sources to minimise haulage requirements
  - 60a Use of temporary surface pipes for distribution of water supply
  - 60b Use of temporary surface pipes for collection of flowback
- CBM. The following adjustments to measures were made:
  - 38a Notification of water demand from fracturing operations to relevant water utilities and competent authorities (impact of groundwater pumping). A high ambition measure added to all options
  - 38b Demand profile for water. Remained in option A only
  - 38c Water management plan. Removed from all options
  - N49 Strategic planning and staged approach of play development to avoid peaks in water demand. Remained in option A only
  - 3a vi Site baseline. Establish water source availability and test for suitability. Remained in option A only
  - 3b vi Monitoring. Water resources availability. A high ambition measure (focussed on active groundwater and surface water level and flow management to address impacts of groundwater pumping) added to all options

- 3b ix Monitoring. Undertake monitoring of water volumes and origin. Remained in option A only
- 60c Site selection close to water sources to minimise haulage requirements. Not selected for any options
- 60a Use of temporary surface pipes for distribution of water supply. Not selected for any options
- 60b Use of temporary surface pipes for collection of flowback. Not selected for any options
- 26d Development of a conceptual model of the zone before work commences covering geology, groundwater flows, pathways, microseismicity and subsequent updating of the model as information becomes available. A high ambition measure added to all options.

5.4 Policy Option Costs

5.4.1 Introduction

For some 230 non-BAU measures (including sub-measures) identified to address (partially or fully) specific environmental risks, costs and benefits were assessed quantitatively or qualitatively.

Quantitative assessment included identification of capital costs (i.e. one-off) as well as annual operating costs, all expressed per well pad, based on the available literature and expert judgement based on practical experience of implementing similar measures in the EU and North America, and also in Australia for CBM. The cost estimates were based on the key assumptions made in the illustrative concession (see Appendix A) and labour costs for operators, external technical experts and competent authorities[37]. All costs were adjusted to 2012 Euro prices using historical exchange rates (annual average) and Eurostat annual average index of Harmonised Index of Consumer Prices (HICP). This approach was consistent with that used for assessment of shale gas (see AMEC (2014)).

Once capital and annual operating costs were identified (for those measures that it was possible and appropriate to quantify), annualised compliance costs were estimated for each measure. Capital cost was assumed to be amortised over 20 years for tight gas and tight oil and 7 years for CBM (i.e. the assumed typical lifetime of the well facilities). For measures where different amortisation periods were applied, this was noted in the key assumptions. Measures and associated costs are based on the illustrative concessions and will vary with concession size and pad lifetimes achieved, potentially leading to economies of scale (or vice versa). A discount rate of 4% was applied.

Based on the annualised compliance cost of individual measures, total annualised compliance costs for different policy options were estimated for tight gas, tight oil and CBM. For Option A, the high end costs assume that the

[37] Labour cost included average hourly wage, non-wage labour cost and overhead of 25%. Mean hourly earnings in 2010, % total wages and salaries and % social security and other labour costs paid for different NACE categories from Eurostat were used to estimate the non-wage labour costs and overhead. The "industry construction and services" category was assumed for operators; "professional, scientific and technical activities" was assumed for technical experts; and "public administration and defence, compulsory social security" was assumed for authorities. Where Member-State-specific statistics were collected, a weighted average of the EU was used for the calculation of labour-based cost components for relevant measures. Labour cost, adjusted to 2012 prices, was assumed to be €39 per hour for operators; €41 for Member State competent authorities; €76 per hour for European Commission (based on labour cost in Belgium) and €59 per hour for external technical experts. The labour cost of external technical experts (i.e. contractor that operators would hire to carry out specific services) is adjusted to reflect 18.7% EU average gross operating rate for architectural and engineering services – technical testing and analysis sector in 2009, as the hourly fee quoted by these experts would likely to include a fee margin on top of the actual labour cost.

level of ambition and thus related cost would not exceed that of Option B. For Option D measures selected as guidance only in Option C were assumed to be compulsory; in addition, High ambition measures were selected rather than a Low ambition measure where previously in Option C a Low ambition measure was selected and a High option was available.

5.4.2 Cost of Measures under Each Policy Option

Annualised Compliance Costs

Table 5.3, Table 5.4 and Table 5.5 present the annualised compliance costs for tight gas, tight oil and CBM respectively for different policy options, showing the split between costs borne by operators and authorities. These costs have been derived by adding the costs of all of the measures that have been quantified and which have been assumed to apply under each option. A detailed list of all measures included in each policy option and their annualised compliance cost is available in Appendix D. By way of comparison, Table 5.6 presents the total annualised compliance costs for shale gas for the policy options from AMEC (2014).

Table 5.3 Tight Gas Annualised Compliance Costs for Policy Options (€ per pad)

Policy Option	Option A[1] Recommendation plus Guidance	Option B Amendment to the *Acquis* plus Guidance	Option C[2] Dedicated Legislation (Directive) + Guidance	Option D Dedicated Legislation (Regulation) + Guidance
Total annualised compliance costs	**0 to 968,000**	**968,000**	**1,019,000**	**1,109,000**
Operators	*0 to 966,000*	*966,000*	*1,012,000*	*1,102,000*
Authorities	*0 to 2,000*	*2,000*	*7,000*	*7,000*

Table 5.4 Tight Oil Annualised Compliance Costs for Policy Options (€ per pad)

Policy Option	Option A[1] Recommendation plus Guidance	Option B Amendment to the *Acquis* plus Guidance	Option C[2] Dedicated Legislation (Directive) + Guidance	Option D Dedicated Legislation (Regulation) + Guidance
Total annualised compliance costs	**0 to 970,000**	**970,000**	**1,022,000**	**1,112,000**
Operators	*0 to 968,000*	*968,000*	*1,015,000*	*1,105,000*
Authorities	*0 to 2,000*	*2,000*	*7,000*	*7,000*

Table 5.5 CBM Annualised Compliance Costs for Policy Options (€ per pad)

Policy Option	Option A[1] Recommendation plus Guidance	Option B Amendment to the *Acquis* plus Guidance	Option C[2] Dedicated Legislation (Directive) + Guidance	Option D Dedicated Legislation (Regulation) + Guidance
Total annualised compliance costs	**0 to 818,000**	**818,000**	**894,000**	**984,000**
Operators	*0 to 817,000*	*817,000*	*880,000*	*970,000*
Authorities	*0 to 1,000*	*1,000*	*14,000*	*14,000*

Table 5.6 Shale Gas Annualised Compliance Costs for Policy Options (€ per pad)

Policy Option	Option A[1] Recommendation plus Guidance	Option B Amendment to the *Acquis* plus Guidance	Option C[2] Dedicated Legislation (Directive) + Guidance	Option D Dedicated Legislation (Regulation) + Guidance
Total annualised compliance costs	**0 to 1,514,000**	**1,514,000**	**1,590,000**	**1,686,000**

Note: Costs have been rounded to the nearest thousand.
1. The cost of Option A will be determined by the level of ambition adopted by Member States. The high end costs for Option A assume that the level ambition and thus related cost would not exceed that of Option B.
2. Costs for Option C may lie between those calculated for Option B and Option C depending on the level of ambition of a Directive, the nature of measures applied and the process of application in Member States.

Compared to annualised compliance costs for shale gas, tight gas and tight oil costs are lower due to a combination of an adjustment to measures selected and the assumed well lifetime, principally the latter (20 year lifetime for tight gas and tight oil vs. 10 year lifetime for shale gas). For CBM, annualised compliance costs are lower than shale gas, tight gas and tight oil due to a combination of an adjustment to measures selected, the smaller number of wells per pad and in the case of (in particular) measure 22a on *key elements to maintain well safety*[38], a scaling of the measure cost to account for the shallower depth and shorter horizontal length of the well compared to the other unconventional hydrocarbons[39].

The measures included in the policy options are considered as strictly non-BAU as they are not specifically required by existing legislation. However, as discussed in section 4.2, some measures are likely to be normal practice by operators. For instance, measure 22a on *key elements to maintain well safety* comprises many elements that are normal industry practice, but are not necessarily specified requirements under existing regulation. Similarly, measure 33b *use of tank level alarms* (so that operators are notified when the volume of chemicals and/or

[38] Full description of the measure is: 'Key elements to maintain well safety such as: blowout preventers, pressure & temperature monitoring and shutdown systems, fire and gas detection, continuous monitoring for leaks and release of gas and liquids, modelling to aid well/HF design, isolate underground source of drinking water prior to drilling, ensure micro-annulus is not formed, casing centralizers to centre casing in hole, select corrosive resistant alloys and high strength steel, fish back casing, maintain appropriate bending radius, triple casing, casing and cementing designed to sustain high pressure and low magnitude seismicity, isolation of the well from aquifers, casings: minimum distance the surface casing extends below aquifer (e.g. 30m below the deepest underground source of drinking water encountered while drilling the well, ref. Environment Agency 2012) and surface casing cemented before reaching depth of e.g. 75m below underground drinking water (ref. AEA 2012). Production casing cemented up to at least 150 metres above the formation where hydraulic fracturing will be carried out (ref. AEA 2012).'

[39] Note that well lifetimes are reported to vary significantly. USEPA (2013) indicates 5-15 years, Amec Foster Wheeler experience in Australia indicates 2-5 years and personal communication with European Gas Ltd (2015) has suggested 15-25 years. Adjusting well lifetime for CBM from 7 to 15 years would result in total annualised compliance costs per pad of Option A of €0 to 506,000, Option B €506,000, Option C €553,000 and Option D €619,000.

fracturing fluid stored in tanks is closed to the tanks' capacity so corrective actions can be implemented) is considered to be likely to be applied. The cost of Option A will be determined by the level of ambition and degree of application of measures adopted by Member States. Hence this option could theoretically incur no costs if a recommendation and guidance are not followed for other UFF and the level of ambition is to maintain the extant interpretation and application of legislation.

Since some of the measures considered in the different policy options are likely to be applied in reality, as per the approach used for shale gas (see AMEC (2014)) to avoid overestimating the annualised compliance costs of policy options , costs of these measures were adjusted downward to reflect a (purely hypothetical) average level of uptake. Specifically, 10% of compliance costs was assumed for the measures that were considered to be *likely to be applied* (i.e. 90% uptake level) and 60% of costs for the measures considered to be *possible to be applied* (i.e. 40% uptake level). Annual compliance costs of policy options, with these adjustments, are shown below in Table 5.7, Table 5.8 and Table 5.9 for tight gas, tight oil and CBM respectively. The percentage uptake figures, suggested by the Commission, are only illustrative and are not intended to be predictors of actual uptake of any individual measure by operators.

It is noted that costs for CBM do not reduce to the same degree as those for tight gas and tight oil. This is primarily due to the cost of the high ambition baseline groundwater monitoring measure and aspects of the geological, hydrogeological and seismic conceptual model measure (in particular, obtaining geomechanical information on fractures, stress, rock strength, in situ fluid pressures, and a 3D seismic survey to identify faults and fractures)[40]. These measures are one-off costs that are not proportional to the scale of the gas produced from well. The measure is assumed not to be 'likely to be applied' or 'possible to be applied' in normal practice hence measure costs are not adjusted down for the policy options. The measure has a significant, €0.2m annualised cost for CBM over the seven year well lifetime (compared to a lower annualised cost for tight gas and tight oil where the same fixed cost is annualised over a 20 year well lifetime). In addition, the number of wells assumed for CBM per pad is lower and the production phase is shorter than for other UFFs[41]. The combination of high initial fixed costs of measures per well, a shorter production period and lower revenue potential of CBM wells results in the proportion of the costs of policy options to expected revenues being greater for CBM (see Section 5.5) although it should be noted that revenues and production periods will vary between sites.

[40] High ambition baseline groundwater monitoring measure, €200k per pad; obtaining geomechanical information on fractures, stress, rock strength, in situ fluid pressures, €48k per pad, and a 3D seismic survey to identify faults and fractures, €60k per pad in all policy options.

[41] As noted above (see footnote 39), well lifetimes are reported to vary significantly (from 2-25 years). In addition, the number of wells per pad are reported to vary due to various well configurations, 1, between 2 and 8, and up to 16 wells per pad have been reported (Amec Foster Wheeler experience in the US and Australia, and personal communication with European Gas Ltd (2015) respectively).

Table 5.7 Tight Gas Annualised Compliance Costs for Policy Options, with Adjustments for Non-BAU Measures that are Likely to be Applied in Practice (€ per pad), and Difference to Annualised Compliance Costs with No Adjustments (€ per pad)

Policy Option	**Option A[1] Recommendation plus Guidance**	**Option B Amendment to the *Acquis* plus Guidance**	**Option C[2] Dedicated Legislation (Directive) + Guidance**	**Option D Dedicated Legislation (Regulation) + Guidance**
Total annualised compliance costs , with adjustment for non-BAU measures *likely to be applied* in practice	0 to 462,000	462,000	505,000	595,000
Operators	*0 to 461,000*	*461,000*	*499,000*	*589,000*
Authorities	*0 to 1,000*	*1,000*	*6,000*	*6,000*
Difference compared to pre-adjustment	*Up to 48%*	*48%*	*50%*	*54%*
Total annualised compliance costs , with adjustment for non-BAU measures *likely to be applied and possible to be applied* in practice	0 to 409,000	409,000	449,000	530,000
Operators	*0 to 408,000*	*408,000*	*443,000*	*524,000*
Authorities	*0 to 1,000*	*1,000*	*6,000*	*6,000*
Difference compared to pre-adjustment	*Up to 42%*	*42%*	*44%*	*48%*

Note: Costs have been rounded to the nearest thousand.
1. The cost of Option A will be determined by the level of ambition adopted by Member States. The high end costs for Option A assume that the level ambition and thus related costs would not exceed the level of Option B.
2. Costs for Option C may lie between those calculated for Option B and Option C depending on the level of ambition of a Directive, the nature of measures applied and the process of application in Member States.

Table 5.8 Tight Oil Annualised Compliance Costs for Policy Options, with Adjustments for Non-BAU Measures that are Likely to be Applied in Practice (€ per pad), and Difference to Annualised Compliance Costs with No Adjustments (€ per pad)

Policy Option	**Option A[1] Recommendation plus Guidance**	**Option B Amendment to the *Acquis* plus Guidance**	**Option C[2] Dedicated Legislation (Directive) + Guidance**	**Option D Dedicated Legislation (Regulation) + Guidance**
Total annualised compliance costs , with adjustment for non-BAU measures *likely to be applied* in practice	0 to 464,000	464,000	507,000	597,000
Operators	*0 to 463,000*	*463,000*	*501,000*	*591,000*
Authorities	*0 to 1,000*	*1,000*	*6,000*	*6,000*
Difference compared to pre-adjustment	*Up to 48%*	*48%*	*50%*	*54%*
Total annualised compliance costs , with adjustment for non-BAU measures *likely to be applied and possible to be applied* in practice	0 to 412,000	412,000	451,000	533,000
Operators	*0 to 411,000*	*411,000*	*445,000*	*527,000*
Authorities	*0 to 1,000*	*1,000*	*6,000*	*6,000*
Difference compared to pre-adjustment	*Up to 42%*	*42%*	*44%*	*48%*

Note: Costs have been rounded to the nearest thousand.
1. The cost of Option A will be determined by the level of ambition adopted by Member States. The high end costs for Option A assume that the level ambition and thus related costs would not exceed the level of Option B.
2. Costs for Option C may lie between those calculated for Option B and Option C depending on the level of ambition of a Directive, the nature of measures applied and the process of application in Member States.

Table 5.9 CBM Annualised Compliance Costs for Policy Options, with Adjustments for Non-BAU Measures that are Likely to be Applied in Practice (€ per pad), and Difference to Annualised Compliance Costs with No Adjustments (€ per pad)

Policy Option	Option A[1] Recommendation plus Guidance	Option B Amendment to the *Acquis* plus Guidance	Option C[2] Dedicated Legislation (Directive) + Guidance	Option D Dedicated Legislation (Regulation) + Guidance
Total annualised compliance costs , with adjustment for non-BAU measures *likely to be applied* in practice	0 to 634,000	634,000	707,000	797,000
Operators	*0 to 633,000*	*633,000*	*693,000*	*783,000*
Authorities	*0 to 1,000*	*1,000*	*14,000*	*14,000*
Difference compared to pre-adjustment	*Up to 77%*	*78%*	*79%*	*81%*
Total annualised compliance costs , with adjustment for non-BAU measures *likely to be applied and possible to be applied* in practice	0 to 574,000	574,000	644,000	722,000
Operators	*0 to 573,000*	*573,000*	*630,000*	*708,000*
Authorities	*0 to 1,000*	*1,000*	*14,000*	*14,000*
Difference compared to pre-adjustment	*Up to 70%*	*70%*	*72%*	*73%*

Note: Costs have been rounded to the nearest thousand.
1. The cost of Option A will be determined by the level of ambition adopted by Member States. The high end costs for Option A assume that the level ambition and thus related costs would not exceed the level of Option B.
2. Costs for Option C may lie between those calculated for Option B and Option C depending on the level of ambition of a Directive, the nature of measures applied and the process of application in Member States.

Administrative Costs of Policy Options

Together with costs to operators and authorities associated with risk mitigation measures as set out above, there would also be costs to both operators and authorities associated with the policy option(s) used to implement the various measures. Section 4.8.7 of AMEC (2014) presents a discussion of the types of costs to operators and authorities that would be likely to arise for each of the policy options together with the baseline option and should be referred to for further detail. Such costs are equally relevant to the administration of the policy options for tight gas, tight oil and CBM.

AMEC (2014) estimates the costs of permitting of unconventional gas installations drawing upon experience of the costs of other similar regimes, in particular, those of carbon capture and storage (CCS) and Industrial Emissions. In summary, costs identified per pad which are equally relevant to tight gas, tight oil and CBM were:

- Total start-up administrative costs associated with administrative costs of a risk management framework for exploration and production: around €22,600 for an operator and €11,000 for the administration;

- Assuming that inspection and compliance checking would need to be undertaken annually , the annual recurring costs for monitoring, reporting and compliance checking would be around €6,100 for operators and €1,600 for the administrations.

These figures are based on individual pads however, an unconventional gas concession would have many pads developed over many years hence efficiencies would be present in permit development as operators and administrators develop related approaches and experience. It is, therefore, not possible to provide a reliable cumulative figure for administrative costs at EU level.

Benefits of Policy Options

Finally it is important to note that it was not possible to provide a monetary estimate of the potential environment benefits of the application of the analysed measures for the different policy options and the evaluation did not directly assess human health risks from incidents as this was specifically excluded from the study terms of reference. However, in any future consideration of which options should be pursued, it will be important to consider the extent of these wider benefits alongside the potential costs to operators and administrations to ensure that the full and correct perspective is taken into account in making policy decisions.

5.5 Policy Option Affordability

For tight gas, tight oil and CBM, it is important to understand the likely financial burden that application of the various risk management measures under each of the policy options would place upon operators. In line with the approach used in AMEC (2014), the estimates of total annualised costs derived in the previous section have been compared to an indicative estimate of the likely revenues that would be gained through a typical unconventional gas facility. It is acknowledged that following the time at which the AMEC (2014) work was carried out, oil and gas prices reduced considerably. To enable direct comparison of affordability with the AMEC (2014) work on shale gas, the same gas prices have been used together with an equivalent (in terms of year) oil price. However, commentary on the potential impact on affordability of a lower oil and gas price is made to account for intervening price fluctuation.

For tight gas, assuming an annual gas production rate of 6-19 mcm (as per shale gas[42]) over a 20 year well lifetime[43], gas production per pad, per year (assuming eight wells per pad) would be in the order of 45-148 mcm.

[42] Production rates of shale and tight gas formations are variable, however, judgement informed by experience in North America indicates that gas production rate is not different due to it being from a tight or shale formation by definition. The same production rate range as used for shale gas in AMEC (2014) is hence used for tight gas.

[43] European Commission data (personal communication based on JRC IET study) suggest 56-185mcm per well based on 30 year lifetime. Taking into account the significant drop-off in production rates for both shale and tight gas seen in the US after c.10 years and typical 10-year gas production rates in the US of around 4-6bcf (120-160mcm), the JRC figures for shale gas have been divided by 10 to provide an estimated annual production value.

The price of natural gas used in AMEC (2014) is used for consistency and was estimated[44] at €0.43 per m^3. The revenues from natural gas sales are therefore estimated as €19-64 million per pad per year (midpoint of €42 million).

For tight oil, assuming an annual oil production rate of 890 m^3 over a 20 year well lifetime, oil production per pad, per year (assuming eight wells per pad) would be in the order of 7,125 m^3. The price of oil in 2012 was approximately €720/m^3 ($100 per barrel) (European Commission (2014)). A 2012 price point has been used to enable an even comparison with the AMEC (2014) shale gas study (and, tight gas and CBM in this study). The revenues from oil sales are therefore estimated as €5.1 million per pad per year.

For CBM, assuming an annual gas production rate of 14 mcm over a seven year well lifetime, gas production per pad, per year (assuming four wells per pad) would be in the order of 8 mcm. A price of natural gas of €0.43 per m^3 is used again for consistency (see above). The revenues from natural gas sales are therefore estimated as €3.5 million per pad per year.

The tables below present the quantified costs under each of the policy options to the potential estimated revenues under different scenarios for the expected uptake of measures in the absence of further EU risk management policies. The estimated compliance costs as a percentage of expected revenues for tight gas are similar in magnitude to those calculated for shale gas (see Section 4.9 of AMEC (2014)). The percentage of expected revenues for CBM and tight oil are higher than for tight gas and shale gas. This is due to the assumed lifetime production volumes and associated revenues and in addition for CBM, the smaller reduction in compliance costs when taking account of ‘likely to be applied’ or ‘possible to be applied’ measures (see Section 5.4.2 for further details on this point).

[44] Gas prices per member state in €/kWh (www.energy.eu, November 2012) were used to derive this value based on final natural gas consumption in 2011 by member state from Eurostat. The figure above was derived by estimating an EU average price, weighted according to consumption by member state. Prices include market price, transport, administrative charges, non-recoverable taxes and duties but exclude recoverable taxes and duties (e.g. VAT).

Table 5.10 Tight Gas Comparison of Costs of Policy Options to Expected Revenues from Natural Gas Sales

Measures Included/Excluded	A Recommendation plus Guidance	B Amendment + Guidance	C Dedicated Legislation (Directive) + Guidance	D Dedicated Legislation (Regulation) + Guidance
Total Annualised Costs of Measures (per pad				
All strictly non-BAU measures	€ 0 - 258,000	€ 966,000	€ 1,012,000	€ 1,102,000
Non-BAU measures except those likely to be applied already [1]	€ 0 - 250,000	€ 461,000	€ 499,000	€ 589,000
Non-BAU measures except those possibly applied already [2]	€ 0 - 218,000	€ 408,000	€ 443,000	€ 524,000
Annualised Costs as a Percentage of Expected Annual Revenues				
All strictly non-BAU measures	0.0 - 0.6%	2.3%	2.4%	2.7%
Non-BAU measures except those likely to be applied already [1]	0.0 - 0.6%	1.1%	1.2%	1.4%
Non-BAU measures except those possibly applied already [2]	0.0 - 0.5%	1.0%	1.1%	1.3%

Notes

1 Takes account of uptake of measures categorised as 'yes' in terms of whether likely to be applied in any case.

2 As [1] plus takes account of uptake of measures categorised as 'possible – high' in terms of whether likely to be applied in any case.

Table 5.11 Tight Oil Comparison of Costs of Policy Options to Expected Revenues from Natural Gas Sales

Measures Included/Excluded	A Recommendation plus Guidance	B Amendment + Guidance	C Dedicated Legislation (Directive) + Guidance	D Dedicated Legislation (Regulation) + Guidance
Total Annualised Costs of Measures (per pad)				
All strictly non-BAU measures	€ 0 - 259,000	€ 968,000	€ 1,015,000	€ 1,105,000
Non-BAU measures except those likely to be applied already [1]	€ 0 - 251,000	€ 463,000	€ 501,000	€ 591,000
Non-BAU measures except those possibly applied already [2]	€ 0 - 219,000	€ 411,000	€ 445,000	€ 527,000
Annualised Costs as a Percentage of Expected Annual Revenues				
All strictly non-BAU measures	0.0 – 5.1%	18.90%	19.80%	21.60%
Non-BAU measures except those likely to be applied already [1]	0.0 – 4.9%	9.10%	9.80%	11.60%
Non-BAU measures except those possibly applied already [2]	0.0 – 4.3%	8.00%	8.70%	10.30%

Notes:

1 Takes account of uptake of measures categorised as ‘yes’ in terms of whether likely to be applied in any case.

2 As [1] plus takes account of uptake of measures categorised as ‘possible – high’ in terms of whether likely to be applied in any case.

Table 5.12 CBM Comparison of Costs of Policy Options to Expected Revenues from Natural Gas Sales

Measures Included/Excluded	A Recommendation plus Guidance	B Amendment + Guidance	C Dedicated Legislation (Directive) + Guidance	D Dedicated Legislation (Regulation) + Guidance
Total Annualised Costs of Measures (per pad				
All strictly non-BAU measures	€ 0 - 356,000	€ 817,000	€ 880,000	€ 970,000
Non-BAU measures except those likely to be applied already [1]	€ 0 - 352,000	€ 633,000	€ 693,000	€ 783,000
Non-BAU measures except those possibly applied already [2]	€ 0 - 315,000	€ 573,000	€ 630,000	€ 708,000
Annualised Costs as a Percentage of Expected Annual Revenues				
All strictly non-BAU measures	0.0 – 10.2%	23.4%	25.2%	27.8%
Non-BAU measures except those likely to be applied already [1]	0.0 – 10.1%	18.1%	19.8%	22.4%
Non-BAU measures except those possibly applied already [2]	0.0 – 9.0%	16.4%	18.0%	20.3%

Notes

1 Takes account of uptake of measures categorised as 'yes' in terms of whether likely to be applied in any case.

2 As [1] plus takes account of uptake of measures categorised as 'possible – high' in terms of whether likely to be applied in any case.

A number of important considerations should be taken into account in interpreting these data:

- The cost of Option A will be determined by the level of ambition adopted, hence cost could theoretically be zero for operators and will increase with higher ambition. Consequently impact on revenues could be nil.
- Indications from the unconventional gas industry suggest that many of the measures considered in the analysis are likely to be adopted (at least in some Member States), regardless of any additional EU risk management framework. This will tend to reduce the overall costs of measures proposed at an EU level.
- There are a number of measures under each policy option that it has not been possible to quantify within the present analysis. This will tend to increase the overall costs provided that they do not qualify as BAU or are otherwise required by Member States.
- The estimates above are highly dependent on a number of assumptions, including:
  - Estimates of gas production volumes per well and the assumed lifetime over which those volumes are realised. For CBM, as noted above, well lifetimes greater than the seven years assumed have been suggested by stakeholders consulted for this report. In addition potential gas production rates of approximately 40-110 mcm per well over the well lifetime have been indicated (European Gas Ltd (2015)) for CBM. Increasing well lifetime from 7 to 15 years and increasing gas production

rate from 14 to 50 mcm over the well lifetime would reduce the annualised costs as a percentage of expected annual revenues for CBM considerably to approximately the following (with non-BAU measures 'likely to be applied' and 'possibly applied' in place):

- Option A from 0.0 – 9.0% to 0.0 – 2.9%
- Option B from 16.4% to 2.9%
- Option C from 18.0% to 3.2%
- Option D from 20.3% to 3.7%

- The estimates are based on best estimates for measure costs using single point values for option cost calculation. Costs may vary and there are uncertainties regarding costs across the large number of measures;
- Variations in oil and gas prices which have seen fluctuation in the period 2012-2015. Oil prices have fallen since 2012[45] whilst gas prices have been broadly stable[46]. The fall in oil price since 2012 will have influenced costs and revenue in the industry. For tight oil using 2015 prices, compared to 2012 prices, this would increase the annualised costs as a percentage of expected annual revenues (with non-BAU measures 'likely to be applied' and 'possibly applied' in place) for the policy options approximately as follows:

  - Option A from 0.0 – 4.3% to 0.0 – 7.2%
  - Option B 8.0% to 13.4%
  - Option from C 8.7% to 14.5%
  - Option D from 10.3 to 17.2%:

- The gas prices used in the analysis, which include some non-recoverable taxes/duties and administrative charges (though they exclude recoverable taxes such as VAT); and
- Assumptions and uncertainties regarding the costs of the individual measures of which each policy option is comprised.

[45] As noted above, oil price in 2012 was approximately €720/m^3 ($100 per barrel) (European Commission (2014)). Oil price in May 2015 is approximately €430/m^3 ($60/barrel) (source nasdaq.com, accessed 19th May 2015).

[46] Energy Prices Report, EU BCN, May 2015 (www.energy.eu) indicates gas price of €0.44/m3 based on natural gas consumption in Europe January to April 2015 compared to €0.43/m3 used in AMEC (2014).

6. Conclusions

This section presents conclusions based on the preceding sections of the report.

Differentiating Conventional Fossil Fuels and Unconventional Fossil Fuels

Regarding the categorisation of UFF:

- There is no universally recognised definition of the distinction between CFF and UFF. What is considered to be UFF may vary over time depending on a combination of resource characteristics, the exploration and production technology used, the economic environment, and the scale, frequency and duration of production from the resource;

- The term 'unconventional' is typically used to identify the use of previously rarely used techniques such as horizontal drilling and hydraulic fracturing. However, these techniques are now applied to many CFF resources and sufficiently frequently that they no longer represent unconventional techniques. An alternative definition refers to hydrocarbons present in the source rock in which the resource was originally formed rather than techniques used; this definition includes shale gas and CBM but excludes tight oil and tight gas where hydrocarbons have migrated from a source rock to a reservoir;

- Potential differentiators between CFF and UFF are:

  - The permeability of the reservoir rock. Shale gas, tight oil and tight gas are found in formations with lower permeability than CFF. However, the permeability of rocks holding CBM is more variable and therefore cannot be readily distinguished from CFF on this basis. There is no clear distinction between CFF and UFF when considering permeability. There is a continuum from highly productive fields characterised by high permeability, through less productive fields, then tight gas and finally to very low permeability shale gas;

  - The geological environment in which CFF and UFF are found. CFF are typically found in discrete accumulations related to a localised geological structural feature and/or stratigraphic conditions (e.g. where a cap rock overlies and contains, a reservoir). In contrast, UFF may be found in much more extensive bodies with more gradational boundaries from the play;

  - The techniques used to exploit CFF versus UFF and in particular the scale of drilling, the extensive use of horizontal wells, and the extent of stimulation required at the production stage for UFF.

- Shale gas, tight gas and tight oil resource may be grouped together as they share many characteristics including: depth; the scale of operations at a well pad; the use of multi-well pads / potential land take; and a requirement for the use of hydraulic fracturing to enable production;

- CBM resources form a separate group due to the shallower depth of operations; the reduced scale of operations at well pads; the use of hydraulic fracturing which is not always required; the smaller volume of fracturing fluid used for fracturing; and the use of chemical additives (not always used). In addition, CBM requires groundwater pumping to reduce pressure, whereas the other forms of UFF do not;

- Stimulation of reservoirs by hydraulic fracturing can be used in both CFF and UFF. The main differences are the pressure and the volume of water used in the process, i.e. whether it is high volume or not and the number of stages of hydraulic fracturing (whether it is a multi-stage process or not);

Categorisation Options

Clear categorisation between CFF and UFF and also between different UFF may enable definition of those hydrocarbons falling under a given policy instrument. There is no single categorisation 'option' that captures all forms of UFF whilst avoiding capturing CFF; however, potential options for categorisation could be based on the following (or combinations thereof):

- Permeability of the reservoir formation (e.g. 0.6mD is used by Germany to determine the point at which a different level of royalty is payable on hydrocarbon production);

- Volume of water used in hydraulic fracturing (for shale gas, tight oil and tight gas). An appropriate value is likely to be in the range 1,000 to 10,000 m^3 per well. A water volume-based option has the advantage of avoiding most CFF and capturing the principal activity that distinguishes UFF from CFF (i.e. *high* volume hydraulic fracturing) whilst being linked to the risks and impacts of UFF. However, if the volume is set at too high a level it will capture only larger-scale operations.

- Pressure applied during hydraulic fracturing (for shale gas, tight oil and tight gas) e.g. more than 700 bar. Specifying a particular (high) pressure applied during hydraulic fracturing would enable capturing of UFF but may also capture some CFF and may not capture shallower (lower pressure) UFF operations as pressure is related to depth of the target formation, even although risks and impacts are potentially similar. Categorisation using pressure may be somewhat arbitrary.

- Depth, due to additional risks presented by shallower operations (proximity to aquifers above wells) and deeper operations (greater pressures required for fracturing and the associated well integrity requirements). However, the use of depth may not capture CBM if the depth is set too deep and there is not a direct link between risk and impacts and therefore this may be viewed as arbitrary.

- Depth for CBM (e.g. operations less than e.g. 1,000 m below ground level) as such operations are more likely to be near aquifers used for drinking water or contributing to surface water flow.

- Volume of pumped groundwater for CBM (operations producing more than e.g. 20 m^3/day / well).

Comparison of Risks and Impacts

Regarding a comparison of risks and impacts with those of shale gas:

- Differences are predominantly within the technical hydraulic fracturing, well completion and production stages;

- CBM is more markedly different than the other UFF types. This is due to the different properties of the reservoir rock (coal), the typically shallower depth, the lower pressures for hydraulic fracturing, and the higher quantity and different characteristics of produced waters associated with the requirement to lower hydrostatic pressure;

- Tight gas and tight oil:

  - Risks and impacts at well pad identification and preparation; well design, drilling, casing and cementing; and well abandonment stages are comparable to shale gas due to the similar nature and potential scale of activities.

  - Risks and impacts associated with the hydraulic fracturing; well completion; and production stages linked to water resource depletion are potentially less significant than for shale gas (in particular for tight gas) due to less water required for the fracturing process.

  - For tight oil, it is possible that risks and impacts at the hydraulic fracturing and production stages regarding groundwater contamination by hydrocarbons (arising from migration of hydrocarbons underground) could be potentially less significant than for shale gas as the heavier hydrocarbon will be less mobile in the underground environment than is the case for gas. Regarding groundwater contamination arising from surface operations, although potentially more significant than for shale gas due to the liquid rather than gaseous nature of the hydrocarbon, once account is taken of BAU risk mitigation measures, risks and impacts for tight oil are judged comparable to tight gas.

- CBM:

  - At the well pad, site identification and preparation, and well design drilling, casing and cementing stages, traffic and air pollution could potentially have lower risks due to the smaller scale and duration of operations and shallower well depths and distances resulting in shorter drilling times;

  - At the technical hydraulic fracturing stage risks and impacts associated with groundwater contamination are potentially more significant for CBM compared to shale gas due to the shallow depth of the target formation compared to shale gas. Equally the risk of fugitive emissions from CBM finding their way through rock strata to the surface is potentially more significant for CBM compared to shale gas operations;

  - Risks and impacts associated with hydraulic fracturing; well completion; and production stages linked to water resource depletion and traffic are potentially less significant than for shale gas due to less water required for the fracturing process and less flowback requiring management and associated transportation;

  - CBM requires pumping of groundwater at the production stage. The abstraction of groundwater presents a risk to water resources in overlying or lateral formations where a hydrogeological connection exists. There is a potentially more significant impact from CBM on water resources compared to shale gas during production due to its greater potential proximity to potable resources. The traffic burden (linked to transportation of produced water) and associated risks and impacts for CBM may potentially be more significant compared to shale gas.

- Risks and impacts at the well abandonment stage are comparable to shale gas due to the similar nature of activities;

- New risks identified for CBM compared to shale gas are:

  - Risks of surface water contamination from greater quantities of actively pumped produced water at the surface which must be managed and treated to the standard required by permits[47]. Increased volumes requiring more frequent transport, treatment and discharge may result in an increased risk of surface water contamination (e.g. through spillage during transfer, treatment plant failure);

  - Risks of increased water resource depletion from groundwater supplies being drawn down towards the target formation;

  - Potential risk of groundwater contamination due to the need for groundwater pumping and associated potential impacts on groundwater resources and quality; and

  - Potential risk of gases seeping through geological strata and being released as fugitive emissions due to the shallower depth and lack of barrier rock strata above the target formation.

Measures Appropriateness and Proportionality

Regarding the appropriateness and proportionality of measures developed for shale gas for other UFF:

- Water resource depletion measures: all measures are judged appropriate for tight oil, tight gas and CBM and all measures are judged proportionate for tight oil and tight gas. Due to lower water demand requirements for CBM, there are a number of measures that are judged to be over-specified for CBM;

- Traffic measures: all measures are considered appropriate for tight oil, tight gas and CBM. Due to fewer vehicle movements associated with water and flowback management, a number of measures are judged to be over-specified for tight oil, tight gas and CBM but may not necessarily be overspecified for the management of produced water (with the exception for CBM of a measure to reduce vehicle movements associated with managing pumped groundwater through site selection close to waste water treatment/disposal facilities to minimise haulage requirements);

- Releases to air: assessed for CBM due to potentially smaller scale activities and pad size and also shallower wells, resulting in shorter duration of diesel powered mobile plant and drilling rigs required. Measures for shale gas are judged appropriate and proportionate for tight oil and CBM;

- Land take: assessed for CBM only and related to potentially smaller scale activities and pad size (relevant measures relate to optimisation (e.g. pad spacing, density), cumulative effects and undertaking Strategic Environment Assessment). Measures are judged appropriate and proportionate for CBM;

[47] Produced water has variable quality (e.g. USEPA (2013) and Umweltbundesamt (2013)) indicate a range from 7 to 128,000 mg/l total dissolved solids in produced water from CBM formations.

- Visual Impact: assessed for CBM only and related to potentially smaller scale activities and pad size (relevant measures relate to the requirement for Environment Impact Assessment and cumulative impacts). Measures are judged to be appropriate and proportionate for CBM;
- Groundwater contamination: assessed for CBM only and related to potentially more significant risks and impacts arising from the shallower depths of formations, potential proximity to potable water resources and potential for affecting overlying groundwater resources due to the need for groundwater pumping in the target formation. All measures are judged appropriate and proportionate to CBM;
- New risks of CBM regarding water resource depletion due to the groundwater pumping required: whilst existing available measures (focussed on addressing groundwater contamination risks) include aspects such as modelling groundwater flows, additional measures may be required to:
  - Model the impact of groundwater pumping on linked groundwater flows and quality;
  - Extend groundwater monitoring requirements; and
  - Require active groundwater level management where potable resources are impacted.

Policy Options Assessment

Sections 5.4 of AMEC (2014) sets out conclusions of the overall effectiveness and efficiency of the general policy options considered, which is not repeated here.

Regarding the costs associated with the selected policy options, the total annualised compliance costs of the selected policy options for operators per pad are estimated at[48]:

Table 6.1 Total Annualised Compliance Costs for Operators of the Selected Policy Options for Operators (€ per pad)

Policy Option	Option A[1] Recommendation plus Guidance	Option B Amendment to the *Acquis* plus Guidance	Option C[2] Dedicated Legislation (Directive) + Guidance	Option D Dedicated Legislation (Regulation) + Guidance
Tight gas	0 to 966,000	966,000	1,012,000	1,102,000
Tight oil	0 to 968,000	968,000	1,015,000	1,105,000
CBM	0 to 817,000	817,000	880,000	970,000

Compared to the option costs for shale gas,[49] annualised costs are lower for tight gas and tight oil due to the greater assumed well lifetime of 20 years compared to that assumed for shale gas of 10 years. For CBM, although the

[48] Refer to notes in tables in Section 5 regarding notes on option cost ranges.

[49] Option A: €0 to €1,512,000; Option B: €1,512,000; Option C: €1,578,000; Option D: €1,674,000.

assumed well lifetime is seven years compared to ten for shale gas, a combination of fewer measures selected and a reduction of the capital cost associated with well safety due to shallower well depth (1,000 m vs. 3,000 m for shale gas) and well horizontal length (250 m vs. 1,350 m for shale gas) combined with fewer wells per pad (four per pad vs. eight per pad for shale gas) reduces costs per pad compliance[50].

The cost of Option A will be determined by the level of ambition adopted and hence could incur no cost for operators and authorities if a low level of ambition is embraced. Taking account of measures that are likely to be applied as normal practice by operators is important so as not to overstate potential compliance costs. The effect of factoring uptake of measures due to the application of normal practice is to reduce the estimated total compliance costs from pre-adjusted estimates. The total annualised compliance costs of the selected policy options per pad taking account of measures that are 'likely' to be applied and those that will 'possibly' be applied are estimated at[51]:

Table 6.2 Total Annualised Compliance Costs, with Adjustment for non-BAU measures *likely to be applied and possible to be applied* (€ per pad)

Policy Option	Option A[1] Recommendation plus Guidance	Option B Amendment to the *Acquis* plus Guidance	Option C[2] Dedicated Legislation (Directive) + Guidance	Option D Dedicated Legislation (Regulation) + Guidance
Tight gas	0 to 409,000	409,000	449,000	530,000
Tight oil	0 to 412,000	412,000	451,000	533,000
CBM	0 to 574,000	574,000	644,000	722,000

It should be noted that the cost estimates exclusively address preventive measures and do not include costs for remediation of accidental events.

The estimated compliance costs as a percentage of expected revenues for tight gas are similar in magnitude to those calculated for shale gas (see AMEC (2014)). The percentage of expected revenues for CBM and tight oil are higher than for tight gas and shale gas. This is due to the assumed lifetime production volumes and associated revenues and in addition for CBM, the smaller reduction in compliance costs when taking account of measures that may be applied already by operators (see Section 5.4.2 for further details on this point). However, for CBM longer well lifetimes and higher gas production rates have been reported than those assumed here, hence compliance costs as a percentage of expected revenues may be lower (see Section 5.5. for further detail on this point).

[50] Note that well lifetimes are reported to vary significantly. USEPA (2013) indicates 5-15 years, Amec Foster Wheeler experience in Australia indicates 2-5 years and personal communication with European Gas Ltd (2015) has suggested 15-25 years. Adjusting well lifetime for CBM from 7 to 15 years would result in total annualised compliance costs per pad of Option A of €0 to 506,000, Option B €506,000, Option C €553,000 and Option D €619,000.

[51] Refer to notes in tables in Section 5 regarding notes on option cost ranges.

Administrative costs associated with the options for tight gas, tight oil and CBM will be analogous to those determined in AMEC (2014) as the general nature of the options remains consistent.

Regarding benefits of the options, the measures in policy options are principally aimed at prevention of possible environmental risks (e.g. technical measures to avoid well failure resulting in groundwater pollution, or effective management of wastewaters at surface level to avoid spills and accidental discharges to surface water and/or land).

7. References

PR= known to be peer-reviewed

AEA, 2012, Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe. Report on behalf of European Commission (PR)

All Consulting, 2012. The Modern Practices of Hydraulic Fracturing: A Focus on Canadian Resources. Prepared for Petroleum Technology Alliance Canada (PTAC) and the Science and Community Environmental Knowledge Fund (SCEK)

AMEC, 2014. Technical Support for Assessing the Need for a Risk Management Framework for Unconventional Gas Extraction: Final Report. For European Commission DG Environment (PR)

BRGM, 2013, Synthèse sur les gaz de houille: exploitation, risques et impacts environnementaux (*A summary of operations and environmental risks and impacts for coal bed methane)*)

Canadian Society for Unconventional Resources (CSUR) (Undated) Understanding Tight Oil

Centrica, 2010, 'Unconventional gas in Europe, response to DECC consultation', 29th October 2010

European Commission, 2014. Commission staff working document. Energy prices and costs report accompanying the document, Energy prices and costs in Europe. COM(2014) 21 final, SWD(2014) 19 final

Canadian Society for Unconventional Resources (CSUR), undated. Understanding Tight Oil

Cuadrilla Elswick Ltd. 2014. Temporary Shale Gas Exploration at Roseacre Wood, Lancashire: EIA Scoping Report

Dart Energy, 2012. Environmental Statement. Proposed development for Coal Bed Methane production including drilling, well site establishment at 14 locations and development of inter-site connection services, site access tracks, a gas delivery and water treatment facility, ancillary facilities infrastructure and associated water outfall point, Letham

Davies, R, Foulger, G, Bindley, A and Styles, P. 2013. Induced Seismicity and Hydraulic Fracturing for the Recovery of Hydrocarbons. Marine and Petroleum Geology. v45. pp. 171-185

Department of Primary Industries Office of Water, New South Wales Government, (2015). Webpage regarding water and coal seam gas accessed 23rd April 2015

Dutch Ministry of Economic Affairs (DMEA). 2013. Additional studies on potential risks and consequences of exploration and production of shale and coal in the Netherlands. Final report research A and B

Electric Power Research Institute (EPRI). 1999. Enhanced oil recovery Scoping Study. TR113836

Environment Agency for England, 2012. Review of assessment procedures for shale gas well casing installation

Environment Agency for England Response, 2014a, to Questionnaire on Parameters for Illustrative Concessions for Tight Gas, Tight Oil and Coal Bed Methane (unpublished)

Environment Agency for England, 2014b. An environmental risk assessment for coal bed, coal mine and abandoned mine methane operations in England

Environment Agency for England, 2014c. Response to European Commission questionnaire on unconventional gas operational parameters. Unpublished

European Commission, 2014. Commission recommendation of 22 January 2014 on minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high-volume hydraulic fracturing (2014/70/EU)

European Gas Ltd, 2015. Response to European Commission questionnaire on unconventional gas operational parameters. Unpublished

Ewen, C. Borchardt, D, Richter, S and Hammerbacher, S., 2012. Hydrofracking Risk Assessment Executive Summary Panel of experts Study concerning the safety and environmental compatibility of hydrofracking for natural gas production from unconventional reservoirs

International Energy Agency, 2012. Golden Rules for a Golden Age of Gas

IHS CERA, 2013. Exporting the North American unconventional gas and tight oil revolution

Haliburton, 2008. Coalbed Methane. Principles and Practice

Lechtenbömer S, Altmann M, Capito S, Matra Z, Weindorf W, Zittel W, 2011. Report for European Parliament. Impacts of Shale Gas and Shale Oil Extraction on the Environment and on Human Health. Directorate General for Internal Policies. Policy Department A, Economic and Scientific Policy; Environment, Public Health and Food Safety

Ewen, C. Borchardt, D, Richter, S and Hammerbacher, S. 2012. Hydrofracking Risk Assessment Executive Summary Panel of experts Study concerning the safety and environmental compatibility of hydrofracking for natural gas production from unconventional reservoirs

Hagemann, B. Wegner, J and Ganzer, L, 2012. Investigation of Hydraulic Fracture Re-Orientation Effects in Tight Gas Reservoirs. Excerpt from the Proceedings of the 2012 COMSOL conference

Halliburton, 2008. Coalbed Methane. Principles and Practice

ICF, 2013. Annex 3 Literature Review of Unconventional Fossil Fuel Resources and Activities in the EU. Macro-economic effects of shale gas extraction in the EU. European Commission DG ENV/DG CLIMA - Ref: ENV.F.1/SER/2012/0046r. Unpublished

King, G. 2012. Hydraulic Fracturing 101. Journal of Petroleum Technology, April 2012 p 34 – 42

Landesamt für Bergbau, Energie und Geologie (LBEG) (State Authority for Mining, Energy and Geology, Germany), 2014. Response to European Commission questionnaire on unconventional gas operational parameters. Unpublished

Lea, J F, Nickens H V and Wells M R. 2008. Gas Well Deliquifaction. 2nd edition. Gulf Drilling Guides

Loftin, 2009. Thirty years of lessons learned – tips and tricks for finding, developing and operating a coalbed methane field. 24th World Gas Conference, Argentina

Mantle M, 2011. Produced Water Reuse and Recycling Challenges and Opportunities across Major Shale Plays

Massachusetts Institute of Technology, 2011. The future of natural gas: an interdisciplinary study

Michigan Department of Environmental Quality, 2011. Supervisor of well instruction 1-2011: High Volume Fracturing Well Completions

Milieu, 2013. Regulatory provisions governing key aspects of unconventional gas extraction in selected EU Member States. 070307/2012/630593/SER/ENV.F1

Ministère de l'écologie, du développement durable et de l'énergie (Ministry of Ecology , Sustainable Development and Energy, France), 2014. Périmètres des Titres Miniers D' Hydrocarbures. 1st Juillet 2014

Nederlandse Aardolie Maatschappij BV (NAM), 2010. Redevelopment Schoonebeeke Oil Field

New York Department of Environmental Conservation, 2014. Proposed revisions to Part 550: Promulgation and Enforcement of Rules and Regulations. Environmental Conservation Law, §§ 23-0305[8] [9])

Sandrea, R, 2012. Evaluating production potential of mature US oil, gas shale plays. Oil and Gas Journal website accessed 06 June 2014

Schmoker, J, 1999. U.S. Geological Survey Assessment Model for Continuous (Unconventional) Oil and Gas Accumulations. The "FORSPAN" Model. U.S. Geological Survey Bulletin 2168

SPE / AAPG /WPC, / SPEE / SEG, 2011. Guidelines for Application of the Petroleum Resources Management System

Standard and Poor, 2011. Is natural gas drilling economic at current prices? Credit Week, December 14

Regeneris Consulting, 2011. Exploration & Production in Lancashire and the UK. A Final Report

Ryder Scott, 2006. Coalbed methane evaluation: A three pronged approach. Presentation at the Ryder Scott Reserves Conference

Shemeta, J E, Eide, E A, Hitzman, M W, Clarke, D D, Detournay, E, Dieterich, J H, and Gibbs, C R, 2012. The potential for induced seismicity in energy technologies. The Leading Edge, 31(12)

Tzimas, E. 2005. Enhanced Oil Recovery using Carbon Dioxide in the European Energy System. European Commission Joint Research Centre

UK Department of Energy and Climate Change, 2010. The unconventional hydrocarbon resources of Britain's onshore basins- shale gas

UK Department of Energy and Climate Change 2013a. The Carboniferous Bowland Shale gas study: geology and resource estimation

UK Department of Energy and Climate Change, 2013b. Onshore oil and gas exploration in the UK: regulation and best practice: England

UK Department of Energy and Climate Change, 2014. Wall map showing current fields and licensing. (at https://www.gov.uk/oil-and-gas-onshore-maps-and-gis-shapefiles)

UK Water Industries Research, 2014. Understanding the potential impacts of the extraction of unconventional gases on the UK water industry: stage 2 report. Report Ref. No. WR09C301

Umweltbundesamt [UB], 2013. Environmental Impacts of Fracking Related to Exploration and Exploitation of Unconventional Natural gas Deposits. Risk Assessment, Recommendations for Action and Evaluation of Relevant Existing Legal Provisions and Administrative Structures

US Department of the Interior, Bureau of Reclamation, 2011. Oil and Gas Produced Water Management and Beneficial Use in the Western United States. Science and Technology Program Report No. 157

US Energy Information Administration (USEIA), 2013. World Shale Gas and Shale Oil Resource Assessment Technically Recoverable Shale Gas and Shale Oil Resources: An Assessment of 137 Shale Formations in 41 Countries outside the United States. Prepared by Advanced Resources International Inc.

US Energy Information Administration (USEIA), 2014. Annual Energy Outlook 2014. With projections to 2040

US Environmental Protection Agency, undated. Enhanced CBM/ CMM Recovery

US Environmental Protection Agency, 2004. Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs Study

US Environmental Protection Agency, 2010. Coalbed Methane Extraction: Detailed Study Report

US Environmental Protection Agency, 2011. Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources

US Environmental Protection Agency, 2013. Technical Development Document for the Coalbed Methane (CBM) Extraction Industry

US Geological Survey, undated. Water Produced with Coal-Bed Methane

US Geological Survey, 2002. Produced Waters Database. U.S. Department of the Interior

US Geological Survey, 2012. Variability of Distributions of Well-Scale Estimated Ultimate Recovery for Continuous (Unconventional) Oil and Gas Resources in the United States. Open-File Report 2012–1118

Appendix A
Illustrative Concession Information

Background

Development of a baseline scenario of 'no policy action' is a critical first step for policy option development to address a risk management framework for unconventional gas extraction in the EU. Considering the uncertainty of future development of unconventional hydrocarbons in Europe, the context of an *illustrative unconventional hydrocarbon concession* is used as a unit concept for evaluation of potential environmental, economic and/or social impacts for both baseline and policy options scenarios.

Methodology

An illustrative unconventional hydrocarbon concession has been developed by first selecting a number of parameters that are required in relation to calculations of per measure costs, including physical aspects (e.g. number of pads/wells), the types and scale of resources required (e.g. fuel/electricity use, water and chemicals used in hydraulic fracturing) and outputs generated (e.g. flowback). For each parameter, either a point estimate or a range of values was assigned, based on available literature.

It should be noted that the characteristics of European other UFF developments are limited and the available literature also refers to conditions of other UFF activities, mainly in North America. Expert judgement from project team members was used to adjust values from outside Europe to better reflect the European context.

Purpose

This appendix has been produced for the purpose of summarising the key parameters and assumptions used to define illustrative unconventional hydrocarbon concessions for other UFF. It is possible that more than one concession is granted per play – total play size would vary extensively from country to country.

The details, including source references, of further parameters and units/unit ranges are provided in the following tables. Some of the parameters (e.g. well depth, volume of water used, flowback and produced, etc.) have been used in estimating compliance and administrative costs in Section 5.

Monitoring

In addition to the parameters set out in this appendix, it was assumed that the following is carried out for the illustrative concessions:

- Baseline monitoring: establishment of the presence of methane in groundwater, including drinking water;
- Baseline monitoring: undertaking the sampling of groundwater;
- Baseline monitoring: Development of a geological, hydrogeological and seismic conceptual model including obtaining geomechanical information on fractures, stress, rock strength, in situ fluid pressures; and
- Monitoring during exploration and production: monitoring of groundwater.

References

Refer to Section 7 for full references.

Illustrative concession: tight gas

#	Parameter	Type	Value	Min	Max	Unit	Notes	Reference
1	Length of horizontal well	Physical	**1,350**	30	3000	m	ICF (2013) horizontal = 900 - 1500 - 3000 m. Ewen et al (2012). 1300 m. LBEG (2014) 30-2150m, suggest 800m (based on tight gas wells of 2 fields). Suggest 1350 as per shale gas. Rock type is not the determining factor.	AMEC expert judgement
2	Depth of vertical well	Physical	**3,000**	1800	5750	m	ICF (2013) depth of injection = 1800 - 3000 - 4200 m. LBEG (2014) 4400-5750 m, suggest 5,000 (based on tight gas wells of 2 fields). Ewen et al (2012) 3500-5000 m. Suggest 3000m as per shale gas. Rock type is not he determining factor.	AMEC expert judgement
3	Area (overground) covered by well pad during construction	Physical	**6**			hectares	Based on historical data. There is no reason why future developments may not be similar size to shale gas however. Assume same area as shale gas.	AMEC expert judgement
4	Area (overground) covered by well pad during operation	Physical	**2.24**			hectares	LBEG (2014) estimates 30 x 30m. Based on historical data. There is no reason why future developments may not be similar size to shale gas. Assume same as shale gas.	AMEC expert judgement
5	Area (underground = gas formation) covered by well pad	Physical	**320**			hectares	LBEG (2014) comment that one can assume nearly the horizontal range of the well path for one direction (s. question 1) multiplied by frac dimension in horizontal range. Ewen et al (2012) estimate 900 hectares for a 14 well pad. Assume same as shale gas as assuming same horizontal well length.	AMEC expert judgement
6	Area per concession	Physical	**800**	7.5	75	km2	LBEG (2014) information indicates average concession size for hydrocarbons (not only limited to tight gas) of 697km2. LBEG (2014) range 1 to 170 km2 for hydrocarbons. Production licences of tight gas specifically range 7.5 to 75 km2. However no reason for difference to shale gas in future if fully developed. Production Licences are depending on sizes of gas fields. On balance, assume same as shale gas for future sceanrio.	AMEC expert judgement
7	# of well pad sites per concession	Physical	**250**			units	Calculated	Calculated
8	Distance between well pad sites	Physical	**1.5**	0.2	2.5	km	LBEG (2014) indicates 200-2500m. Suggest 1500m which is consistent with Ewen et al (2012).	Ewen et al (2012) LBEG (2014)
9	Area occupied by well installations	Physical	**0.7%**			% of the land area (concession)	Calculated	Calculated
10	# of well heads per well pad	Physical	**8**	1	14	units per well pad	LBEG (2014) indicates 1 well per pad based on historic data. Ewen et al (2012) indicate well pads with up to 14 wells. Assume same as shale gas.	AMEC expert judgement
11	Vertical drilling per day	Physical	**110**			metres / day	LBEG (2014) - indicates 15 - 65 days, 35 days proposed. No differentiation between vertical and horizontal drilling however. LBEG (2014) no. appears low. No reason for difference with shale gas.	AMEC expert judgement
12	Horizontal drilling per day	Physical	**55**	15	65	metres / day	LBEG (2014) - indicates 15 - 65 days, 35 days proposed. No differentiation between vertical and horizontal drilling however. No reason for difference with shale gas.	AMEC expert judgement
13	Days required for vertical drilling	Time	**27**			days / well	Calculated: depth of well divided by drilling length per day	Calculated
14	Days required for horizontal drilling	Time	**25**			days / well	Calculated: depth of well divided by drilling length per day	Calculated
15	Duration of the drilling stage	Time	**52**	100	200	days / well	LBEG (2014) indicates 100-200 days, 120 days proposed. Calculated based on assumptions.	Calculated
16	Rate of mud generation from drilling	Waste		0.47	0.63	m^3 per metre drilled	Original assumptions for shale gas: 0.9 to 1.2 barrels of mud generated per foot drilled. Converted to metric units. Assume as per shale gas.	AMEC expert judgement
17	Mud generated from drilling	Waste	**1,650**	1,410	1,890	m^3	Calculated from depth of well drilled and rate of mud generation (average is used)	AMEC expert judgement
18	Expected # of wells developed in the EU	Physical	**No data**					
19	Expected # of well pads developed in the EU	Physical	**No data**					
20	Required vol. of fracturing fluid in hydraulic fracturing	Resource	**6,000**	100	12000	m^3 per fracturing	LBEG (2014) 100-1000m3. Ewen et al (2012) 1600 per frack for 10 fracks. ICF (2013) 200--1400-7100 m3. UB (2013) 12000 m3. Danish Energy Ministry (2012), Communication to European Commission (in AEA 2012): 7,000-8,000m3 from .	Assumption based on ranges identified
21	Number of fractures per well during lifetime	Physical	**2**	1	9	times	LBEG (2014) indicates all wells are still in use, and wells may be refracturing in future. Newer wells have more (up to 9) fracs well, older wells have only 1-2 fracs per well. Assume 2 fracs per well over lifetime.	Assumption based on LBEG (2014) data.
22	% Flowback, out of total vol. of fracture fluid used per fracture	Waste	**25%**	17%	35%	%	Data from 3 wells = 17% - UB (2013) 70 - 430 - 2100 m^3 ICF (2013) = approximately 30-35%.	Assumption based on UB (2013) and ICF (2013)
23	Flowback from fracture fluid (volume) per fracture	Waste	**1,500**			m^3 per fracturing	Calculated based on volume of fracture fluid used and % flowback	Calculated
24	Flowback from fracturing fluid (volume) per well lifetime	Waste	**3,000**			m^3 per well	Calculated based on volume of flowback and number of fractures per well lifetime	Calculated
25	% Flowback recycle rate	Waste	**35%**			%		AMEC expert judgement
26	Volume of recycled fracture fluid, to be used for further fracturing (volume)	Waste	**2100**			m^3 per fracturing	Calculated based on volume of fracturing fluid used and % recycling	Calculated
27	Fracturing fluid - water content	Resource	**90%**			% of total volume	Calculated from % additives and proppant	Calculated
28	Volume of water (fresh or recycled) in fracture fluid per fracturing	Resource	**5,400**			m^3 per fracturing	Calculated based on volume of fracture fluid and proportion of water in fracture fluid	Calculated
29	Not used							
30	Water use in fracturing per well lifetime	Resource	**10,950**			m^3 per well	Calculated	Calculated
31	Proppant content in fracturing fluid	Resource	**9.50%**	2.0%	25%	%	Larger % related to small volumes. ICF (2013) = 0 - 0.1 - 0.7 million kg/well. UB (2013) 2%. Ewen et al (2012) 2%. LBEG (2014) indicates 60-250t in 100-1000m3. Assume as per shale gas.	AMEC expert judgement
32	Density of proppant	Resource	**1.95**			tonnes/m^3	Assumed to be equal to density of wet sand	EC
33	Quantity of proppant in fracture fluid per fracturing	Resource	**1,112**			tonnes	Calculated based on volume of fracture fluid, proportion of proppant in fracture fluid and density of proppant	Calculated
34	Quantity of proppant in fracture fluid per well lifetime	Resource	**2,223**			tonnes	Calculated based on volume of proppant and number of fractures during well lifetime	Calculated
35	Fracturing fluid - additives	Resource	**0.50%**	0.001%	13.00%	%	Large amounts relate to older activity. Assume similar to more recent shale gas operations (0.5%)	AMEC expert judgement
36	Volume of additives in fracture fluid per fracturing	Resource	**30**			m^3	Calculated based on volume of fracture fluid and proportion of additives in fracture fluid	Calculated
37	Volume of additives in fracture fluid per well lifetime	Resource	**60**			m^3	Calculated based on volume of additives and number of fractures during well lifetime	Calculated
38	Required water storage availability	Resource	**6,000**			m^3	Calculated based on volume of fracture fluid.	Calculated
39	Required proppant storage availability	Resource	**1,112**			tonnes	Equivalent to required volume for one fracture	Calculated
40	Required additive storage availability	Resource	**30**			m^3	Equivalent to required volume for one fracture	Calculated
41	Storage capacity per truck	Resource	**40**			m^3		AEAT (2012)
42	# of truck movements to manage freshwater in 2 hydraulic fracturing	Resource	**274**			trucks	Calculated: required water divided by storage capacity per truck	Calculated
43	# of truck movements to manage flowback in 2 hydraulic fracturing	Resource	**49**			trucks	Calculated	Calculated
44	# of site construction truck movements	Resource	**135**			trucks	Assume same pad size as shale gas. Ewen et al (2012) indicates 70.	AMEC expert judgement
45	# drilling stage truck movements	Resource	**515**			trucks	Estimated value	AMEC expert judgement
46	Cuttings additional volume from a horizontal well compared to a vertical well	Resource	**40%**			greater compared to a vertical well	Horizontal drilling penetrates a greater linear distance of rock and therefore produces a larger volume of drill cuttings than does a well drilled vertically to the same depth below the ground surface	NYSDES (2011)
47	Salinity of produced water	Waste		5,000	200,000	ppm	Formation specific. Assume as per shale gas.	AMEC expert judgement
48	Types and levels of contaminants in flowback water	Waste					See Table in source reference for information on contaminants. Formation specific. Assume as per shale gas. UB (2013) notes NORM, mercury, BTEX toxic metals.	Table 2 of AEAT (2012)
49	Gas production (URR)	Output		56	185	mcm per well	URR is assumed to be comparable with shale gas. Indications from experience in N America is that their shale gas and tight gas wells are comparable with some more or less productive - but this not dependent on whethr shale gas or tight gas specifically. JRC IET study indicate 56-185 mcm over 30 year lifetime. (Note: USGS 2012 indicates a estimated ultimate recovery range of 0.044-1.657 bcf (1.2 to 46.9 mcm) with an average of 17.2 mcm. Note that lifetime of well is not stated.).	JRC IET study
50	Re-fracturing (occurrence)	Time	**1**	0	0	over a well lifetime		LBEG (2014)
51	Well lifetime	Time	**20**		30	years	LBEG (2014) indicates wells remain open with oldest from early 1980s and latest from 2008. Suggest possible 30+ year lifetime although could be similar to shale gas. Assume 20 years - could be an argument to set at 10 years as per shale gas.	Assumption based on LBEG (2014) data.
52	Fuel/energy demand	Resource		1500	3000	kW	As shale gas	AMEC expert judgement
53	Volume of produced water	Waste	**0.62**	0.01	1.72	m3/well/day	Low = <200 gallon (0.75m3) per MMCF. Medium = 200-1000 gallon (0.75 - 3.78m3) per MMCF. High = >1000 gallon (>3.78m3) per MMCF. Figures here are calculated based on ranges and URR over 10 years. Value based on average of overall ranges calculated - see produced water sheet.	Mantle (2011)

Illustrative concession: tight oil

#	Parameter	Type	Value	Min	Max	Unit	Notes	Reference
1	Length of horizontal well	Physical	**1,350**	800	4500	m	ICF (2013) horizontal = 1200 - 2400 - 4500 m Suggest 1350 as per shale gas. CSUR (undated)/Halliburton (2008) 800 m. Rock type is not the determining factor.	AMEC expert judgement
2	Depth of vertical well	Physical	**3,000**	600	3600	m	ICF (2013) depth of injection = 1200 - 2400 - 3600 m. Suggest 3000 as per shale gas. Rock type is not the determining factor. All Consulting (2012) = 600 to 2,900 m in Canada	Assumption based on ranges identified
3	Area (overground) covered by well pad during construction	Physical	**6**			hectares	Assume as per shale & tight gas.	AMEC expert judgement
4	Area (overground) covered by well pad during operation	Physical	**2.24**			hectares	Assume as per shale & tight gas.	AMEC expert judgement
5	Area (underground = oil formation) covered by well pad	Physical	**320**			hectares	Assume as per shale & tight gas.	AMEC expert judgement
6	Area per concession	Physical	**800**			km2	Assume as per shale & tight gas.	AMEC expert judgement
7	# of well pad sites per concession	Physical	**250**			units	Calculated	Calculated
8	Distance between well pad sites	Physical	**1.5**	0.5	2	km	Assume as per shale & tight gas.	AMEC expert judgement
9	Area occupied by well installations	Physical	**0.7%**			% of the land area (concession)	Calculated	Calculated
10	# of well heads per well pad	Physical	**8**	1	14	units per well pad	Assume as per shale & tight gas.	AMEC expert judgement
11	Vertical drilling per day	Physical	**110**	15	110	metres / day	Assume as per shale & tight gas.	AMEC expert judgement
12	Horizontal drilling per day	Physical	**55**	15	65	metres / day	Assume as per shale & tight gas.	AMEC expert judgement
13	Days required for vertical drilling	Time	**27**			days / well	Calculated: depth of well divided by drilling length per day	Calculated
14	Days required for horizontal drilling	Time	**25**			days / well	Calculated: depth of well divided by drilling length per day	Calculated
15	Duration of the drilling stage	Time	**52**	100	200	days / well	Calculated	Calculated
16	Rate of mud generation from drilling	Waste		0.47	0.63	m^3 per metre drilled	Original assumptions for shale gas 0.9 to 1.2 barrels of mud generated per foot drilled. Converted to metric units. Assume as per shale gas.	AMEC expert judgement
17	Mud generated from drilling	Waste	**1,650**	1,410	1,890	m^3	Calculated from depth of well drilled and rate of mud generation (average is used)	Calculated
18	Expected # of wells developed in the EU	Physical	**No data**					
19	Expected # of well pads developed in the EU	Physical	**No data**					
20	Required vol. of fracturing fluid in hydraulic fracturing	Resource	**11,400**	500	25600	m^3 per fracturing	ICF (2013) 5700-11400-25600 m3 All Consulting (2012) 500m3	All Consulting (2012) ICF (2013)
21	Number of fractures per well during lifetime	Physical	**2**			times	For tight gas, LBEG (2014) indicates all wells are still in use, and wells may be refracturing in future. Newer wells have more (up to 9) fracs well, older wells have only 1-2 fracs per well. Assume 2 fracs per well over lifetime. Assume as per tight gas.	Assumption based on LBEG (2014) data.
22	% Flowback, out of total vol. of fracture fluid used per fracture	Waste	**35%**	10%	60%	%	3400 - 6800 - 15300 m^3 ICF (2013)	ICF (2013)
23	Flowback from fracture fluid (volume) per fracture	Waste	**3,990**			m^3 per fracturing	Calculated based on volume of fracture fluid used and % flowback	Calculated
24	Flowback from fracturing fluid (volume) per well lifetime	Waste	**7,980**			m^3 per well	Calculated based on volume of flowback and number of fractures per well lifetime	Calculated
25	% Flowback recycle rate	Waste	**35%**			%	Assum as per tight and shale gas.	AMEC expert judgement
26	Volume of recycled fracture fluid, to be used for further fracturing (volume)	Waste	**3990**			m^3 per fracturing	Calculated based on volume of fracturing fluid used and % recycling	Calculated
27	Fracturing fluid - water content	Resource	**90%**			% of total volume	0.5 - 1.1 - 2.5 kg/well ICF (2013) Assume as per shale and tight gas.	AMEC expert judgement
28	Volume of water (fresh or recycled) in fracture fluid per fracturing	Resource	**10,260**			m^3 per fracturing	Calculated based on volume of fracture fluid and proportion of water in fracture fluid	Calculated
29	Not used							
30	Water use in fracturing per well lifetime	Resource	**20,007**			m^3 per well	Calculated	Calculated
31	Proppant content in fracturing fluid	Resource	**9.50%**			%	ICF (2013) = 0.5 - 1.1 - 2.5 million kg/well Assume as per shale and tight gas.	AMEC expert judgement
32	Density of proppant	Resource	**1.95**			tonnes/m^3	Assumed to be equal to density of wet sand	EC
33	Quantity of proppant in fracture fluid per fracturing	Resource	**2,112**			tonnes	Calculated based on volume of fracture fluid, proportion of proppant in fracture fluid and density of proppant	Calculated
34	Quantity of proppant in fracture fluid per well lifetime	Resource	**4,224**			tonnes	Calculated based on volume of proppant and number of fractures during well lifetime	Calculated
35	Fracturing fluid - additives	Resource	**0.50%**			%	Assume as per shale and tight gas.	AMEC expert judgement
36	Volume of additives in fracture fluid per fracturing	Resource	**57**			m^3	Calculated based on volume of fracture fluid and proportion of additives in fracture fluid	Calculated
37	Volume of additives in fracture fluid per well lifetime	Resource	**114**			m^3	Calculated based on volume of additives and number of fractures during well lifetime	Calculated
38	Required water storage availability	Resource	**11,400**			m^3	Calculated based on volume of fracture fluid.	Calculated
39	Required proppant storage availability	Resource	**2,112**			tonnes	Equivalent to required volume for one fracture	Calculated
40	Required additive storage availability	Resource	**57**			m^3	Equivalent to required volume for one fracture	Calculated
41	Storage capacity per truck	Resource	**40**			m^3		AEAT (2012)
42	# of truck movements to manage freshwater in 2 hydraulic fracturing	Resource	**500**			trucks	Calculated: required water divided by storage capacity per truck	Calculated
43	# of truck movements to manage flowback in 2 hydraulic fracturing	Resource	**130**			trucks	Calculated	Calculated
44	# of site construction truck movements	Resource	**135**			trucks	Assume same pad size as shale & tight gas. Ewen et al (2012) indicates 70.	AMEC expert judgement
45	# drilling stage truck movements	Resource	**515**			trucks	Assume as per shale and tight gas.	AMEC expert judgement
46	Cuttings additional volume from a horizontal well compared to a vertical well	Resource	**40%**			greater compared to a vertical well	Horizontal drilling penetrates a greater linear distance of rock and therefore produces a larger volume of drill cuttings than does a well drilled vertically to the same depth below the ground surface	NYSDES (2011)
47	Salinity of produced water	Waste		211	200,000	ppm	All Consulting (2012) 211 to 107,000 mg/l as chloride. AEAT (2012) for shale gas indicates upto 200,000. Salinity if highly formation specific. Assume as per shale gas.	All Consulting (2012) AEAT (2012)
48	Types and levels of contaminants in flowback water	Waste					Formation specific. Assume as per shale gas but with the addition of heavier hydrocarbons associated with oil also present. UB (2013) notes NORM, mercury, BTEX toxic metals.	Table 2 of AEAT (2012)
49	Oil production (URR)	Output	**17,807**			m3 per well	Based on 168,000 US petroleum barrels estimated ultimate recovery per well for a 30 year lifetime (26,710m3), adjusted to the assumed well lifetime. These are not used in calculation of costs for individual measures	US EAI 2014
50	Re-fracturing (occurrence)	Time	**1**	1	9	over a well lifetime	Assume as per shale and tight gas.	AMEC expert judgement
51	Well lifetime	Time	**20**		30	years	Assume as per tight gas.	AMEC expert judgement
52	Fuel/energy demand	Resource		1500	3000	kW	Assume as per tight gas.	AMEC expert judgement
53	Volume of produced water	Waste	**n/a**				Water is miixed with oil	AMEC expert judgement

Illustrative concession: coal bed methane

#	Parameter	Type	Value	Min	Max	Unit	Notes	Reference
1	Length of horizontal well	Physical	**250**	50	1200	m	ICF (2013): 300-1200 AMEC AU view: 50-100m AMEC US view: horizontal not used in CBM.	Based on: ICF (2013) AMEC AU expert
2	Depth of vertical well	Physical	**1,000**	200	1500	m	Dart Energy (2012) 850m. ICF (2013) depth of injection = 500 - 900 - 1500 m. EA (2014) 600 to 1100m (target at 850m). All Consulting (2012) 1,000 m in Munsterlander-Becker Region, Germany AMEC AU expert: 200-1200m	Based on: ICF (2013) EA (2014) All Consulting (2012) AMEC AU expert
3	Area (overground) covered by well pad during construction	Physical	**1.1**			hectares per pad	Assumption based on factor between construction (6 hec) and production (2.24 hec) pad size for shale gas multiplied by known pad size.	Assumption. Calculated
4	Area (overground) covered by well pad during operation	Physical	**0.4**	0.02	1	hectares per pad	Dart Energy (2012), 0.4 hectares and 14 x pad arrangement (combination of water pumping and gas extraction wells) EA (2014), 1.0 hectares. AMEC AU expert suggests 0.02-0,04 hectares.	Based on: Dart Energy (2012) EA (2014) AMEC AU expert
5	Area (underground = gas formation) covered by well pad	Physical	**20**	0.5	20	hectares	AMEC AU expert: 5,000-10,000 m2 AMEC US: 40-60 acres/well. Assume 50 acres = 20 hectares	AMEC US expert (example well layout)
6	Area per concession	Physical	**800**	100	1860	km2	Data from CBM concession (permitted area) sizes in France (2014). EGL, Bleue Lorraine Sud 264 km², EGL, Lons le saunier 1860 km², Gazonor, Valenciennois, 432 km², Gazonor, Sud midi, 929 km². Average = 871 km2. Ministère de l'écologie, du développement durable et de l'énergie 2014. AMEC AU expert: 100-400km2. Assume as per other UFFs.	Based on: Ministère de l'écologie, du développement durable et de l'énergie AMEC AU expert (2014)
7	# of well pad sites per concession	Physical	**250**			number	Assumed whole concession is not in production. Assume same number of well pads as per shale gas.	Assumption
8	Distance between well pad sites	Physical	**1.5**	0.5	4	km	Ewen et al (2012): 1.5 km. AMEC AU expert: 1-4km. AMEC US: 0.5km Note. Spacing unlikely to be consistent due to geological conditions, i.e. clusters may exist.	Based on: Ewen et al (2012) AMEC AU expert
9	Area occupied by well installations	Physical	**0.13%**			% of the land area (concession)	Calculated	Calculated
10	# of well heads per well pad	Physical	**4**	1	8	units per well pad	EA (2014) indicates 4 wells on pilot site. Dart Energy (2012) indicates single. AMEC AU expert: 2-8 wells per pad. AMEC US view: one well per pad. Dependant on well configuration.	Based on: Dart Energy (2012) EA (2014) AMEC AU expert
11	Vertical drilling per day	Physical	**110**			metres / day	Assume as per tight gas.	As shale gas. AMEC expert judgement.
12	Horizontal drilling per day	Physical	**55**	15	65	metres / day	Assume as per tight gas.	AMEC expert judgement.
13	Days required for vertical drilling	Time	**9**	9	21	days / well	Calculated: depth of well divided by drilling length per day Dart (2012) suggests 21 days for 850m	Calculated
14	Days required for horizontal drilling	Time	**5**	5	14	days / well	Calculated: depth of well divided by drilling length per day Dart suggests 14 days	Calculated
15	Duration of the drilling stage	Time	**14**	14	35	days / well	Calculated	Calculated
16	Rate of mud generation from drilling	Waste	**0.11**			m^3 per metre drilled	Equivalent to 0.11m^3 per m drilled (180m^3 / 1600m well length + depth)	EA (2014)
17	Mud generated from drilling	Waste	**110**			m^3	Calculated	Calculated
18	Expected # of wells developed in the EU	Physical	**No data**					
19	Expected # of well pads developed in the EU	Physical	**No data**					
20	Required vol. of fracturing fluid in hydraulic fracturing	Resource	**500**	0	4700	m^3 per fracturing	ICF (2013)= 0 - 100 - 4700m3 USEPA (2004) 220-570m3/well USEPA (2011) = 200 - 1500m3/well	Assumption based on ranges identified
21	Number of fractures per well during lifetime	Physical	**2**			times	USEPA (2004) suggests refracturing is typical. Assume 2 fractures over lifetime (i.e. 1 refracture)	USEPA (2004)
22	% Flowback, out of total vol. of fracture fluid used per fracture	Waste	**70%**	61%	82%	%	CBM dewaters well - so flowback and production are different to other UFF. Assume mid point at approx 70%.	USEPA (2004)
23	Flowback from fracture fluid (volume) per fracture	Waste	**350**			m^3 per fracturing	Calculated based on volume of fracture fluid used and % flowback	Calculated
24	Flowback from fracturing fluid (volume) per well lifetime	Waste	**700**			m^3 per well	Calculated based on volume of flowback and number of fractures per well lifetime	Calculated
25	% Flowback recycle rate	Waste	**35%**			%	Assum as per tight and shale gas.	AMEC expert judgement.
26	Volume of recycled fracture fluid, to be used for further fracturing (volume)	Waste	**175**			m^3 per fracturing	Calculated based on volume of fracturing fluid used and % recycling	Calculated
27	Fracturing fluid - water content	Resource	**91.5%**			% of total volume	Calculated	Calculated
28	Volume of water (fresh or recycled) in fracture fluid per fracturing	Resource	**458**			m^3 per fracturing	Calculated based on volume of fracture fluid and proportion of water in fracture fluid	
29	Not used							
30	Water use in fracturing per well lifetime	Resource	**755**			m^3 per well	Calculated	Calculated
31	Proppant content in fracturing fluid	Resource	**8.00%**	0.0%	8%	%	ICF (2013) = 0.0 - 0.0 - 0.5 million kg/well. CBM may not use proppant Halliburton (2008) indicates 8%	Halliburton (2008)
32	Density of proppant	Resource	**1.95**			tonnes/m^3	Assumed to be equal to density of wet sand	EC
33	Quantity of proppant in fracture fluid per fracturing	Resource	**78**			tonnes	Calculated based on volume of fracture fluid, proportion of proppant in fracture fluid and density of proppant	Calculated
34	Quantity of proppant in fracture fluid per well lifetime	Resource	**156**			tonnes	Calculated based on volume of proppant and number of fractures during well lifetime	Calculated
35	Fracturing fluid - additives	Resource	**0.50%**			%	CBM may not use additives/proppant.	AMEC expert judgement.
36	Volume of additives in fracture fluid per fracturing	Resource	**2.5**			m^3	Calculated based on volume of fracture fluid and proportion of additives in fracture fluid	Calculated
37	Volume of additives in fracture fluid per well lifetime	Resource	**5**			m^3	Calculated based on volume of additives and number of fractures during well lifetime	Calculated
38	Required water storage availability	Resource	**500**			m^3	Calculated based on volume of fracture fluid.	Calculated
39	Required proppant storage availability	Resource	**78**			tonnes	Equivalent to required volume for one fracture	Calculated
40	Required additive storage availability	Resource	**2.5**			m^3	Equivalent to required volume for one fracture	Calculated
41	Storage capacity per truck	Resource	**40**			m^3		AEAT (2012)
42	# of truck movements to manage freshwater in 2 hydraulic fracturing	Resource	**19**			trucks	Calculated: required water divided by storage capacity per truck	Calculated
43	# of truck movements to manage flowback in 2 hydraulic fracturing	Resource	**11**			trucks	Calculated	Calculated
44	# of site construction truck movements	Resource	**120**			trucks		Dart Energy (2012)
45	# drilling stage truck movements	Resource	**280**			trucks	Based on site with multiple laterals operating for 90 days (could be on the high side).	Dart Energy (2012)
46	Cuttings additional volume from a horizontal well compared to a vertical well	Resource	**40%**			greater compared to a vertical well	Horizontal drilling penetrates a greater linear distance of rock and therefore produces a larger volume of drill cuttings than does a well drilled vertically to the same depth below the ground surface	NYSDES (2011)
47	Salinity of produced water	Waste		7	128,000	ppm	Formation specific. Chloride. USEPA (2013): 7 to 34290 mg/l TDS. UB (2013): 1730-128000mg/l. Dart Energy (2012): 4500 mg/l. AMEC Aus: 3,000-12,000 TDS mg/l	USEPA (2013) & UB (2013)
48	Types and levels of contaminants in flowback water	Waste					Highly variable, freshwater to brine - salinity as per produced water.	USEPA (2004) USEPA (2013)
49	Gas production (URR)	Output	**14**	0.9	258	mcm per well	USEPA (2004) present production rates for a number fields. Indicates Ave annual production rate per well of 0.3-8.6 mcm, average 2.1 mcm (2.1-60.1 mcm over 7 year liftime, average 14.4 mcm). USGS (2012) indicates a estimated ultimate recovery range of 0.032-9.128 bcf (0.9 to 258 mcm) with an average of 14.2 mcm. Assume 14.3 mcm over lifetime. (Alternatively: USEPA (2010) indicates 60-500 Mcf/day per basin (1.7 - 14.1 million m^3). Potential to roughly estimate m^3 per day based on well numbers = approx 0.025 million m^3 per day, or 0.025 x 365 days x 7 years = 63 million m^3 over lifetime of well).	AMEC expert judgement.
50	Re-fracturing (occurrence)	Time	**1**			over a well lifetime	USEPA (2004) suggests refracturing is typical. Assume 2 fractures over lifetime (i.e. 1 refracture)	USEPA (2004)
51	Well lifetime	Time	**7**	2	15	years	USEPA (2013): 5-15 years AMEC AU expert: 2-5 years	Based on: USEPA (2013) AMEC AU expert
52	Fuel/energy demand	Resource	**No data**			kW		
53	Volume of produced water	Waste	**35**	1.00	65.00	m3/day/well	Dart Energy (2012) and EA (2014) indicate between 1 and 40 m3/day/well. IEA (2012) indicates up to 65m3/day/well	Dart Energy (2012) EA (2014) IEA (2012)

Appendix B
Measures

Measures assumed 'likely to be applied'[52] are in blue text (based on expert judgment). Only 'Aspects' deemed not comparable to shale gas following screening are presented (see Section 3.3).

Aspect	Measure ref.	Description	Sub-measure description
Water resource depletion	38a	Notification of water demand from fracturing operations to relevant water utilities and competent authorities	
	38b	Demand profile for water (tight gas and tight oil only)	
	N49	Strategic planning and staged approach of play development to avoid peaks in water demand	
	38c	Water management plan	
	3a vi	Site baseline Establish water source availability and test for suitability (tight gas and tight oil only)	
	3b vi	Monitoring Water resources availability	
	3b ix	Monitoring Undertake monitoring of water volumes and origin	
	38d	Reuse of flowback and produced water for fracturing	
	38e	Use of lower quality water for fracturing (e.g. non-potable ground / surface water, rainwater harvesting, saline aquifers, sea water, treated industrial waterwaters)	
Traffic	59a	Traffic impact assessment including consideration of noise, emissions and other relevant impacts	
	59b	Transport management plan (including consideration of available road, rail, waterway infrastructure)	
	60c	Site selection close to water sources to minimise haulage requirements	
	61b i	Minimise resources demands and hence traffic movements through (i) water management plans and (ii) wastewater management plans	i) water management plans to minimise water demands and hence traffic movements.
	61b ii	Minimise resources demands and hence traffic movements through (i) water management plans and (ii) wastewater management plans	ii) wastewater management plans to minimise water demands and hence traffic movements.
	61c	Site selection close to flowback treatment / disposal facilities to minimise haulage requirements	
	3a vii	Site baseline Undertake transport and traffic study.	LOW AMBITION Undertake transport and traffic study. Liaise with highway authority and identify relevant routes to/from well pad
	3a vii	Site baseline Undertake transport and traffic study.	HIGH AMBITION Undertake transport and traffic study. As per LOW plus traffic survey and traffic modelling

[52] For complete list relevant to shale gas see section 3 of and Table E2 in Appendix E of AMEC (2014).

Aspect	Measure ref.	Description	Sub-measure description
	3b vii	Monitoring Undertake monitoring of traffic numbers and patterns	
	60a	Use of temporary surface pipes for distribution of water supply	
	60b	Use of temporary surface pipes for collection of flowback	
	61a	Use of temporary surface pipes for collection of produced water	
Releases to air	59d	Use of vehicles (water, chemicals, waste trucking) that meet minimum air emission standards e.g. EURO standards	
	N54	Encourage industry voluntary approach to reduce air pollutants and greenhouse gases	
	16b i	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	Low emission power supply (switching to LPG)
	16b ii	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	Low emission power supply (switching to grid electricity)
	16d	Application of abatement techniques to minimise emissions (assumed SCR for NOx and Diesel Particulate Filter (DPF) for PM).	
	17c	Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network)	LOW AMBITION Flares or incinerators to reduce emissions from fracturing fluid at exploration stage
	17c	Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network)	HIGH AMBITION As LOW AMBITION with no audible or visible flaring
	3a i	Site baseline Undertake sampling of air quality	
	3b i	Monitoring Undertake monitoring of air quality	
	16a	Preparation of an emissions reduction plan (reduced emission completions) including an assessment of potential local air quality impacts including implications for compliance with ambient air quality limit values	
	17b	Reduced emission completions (REC) to eliminate gas venting: prohibit venting of gas; capture and cleaning for use of gas released from fracture fluid and produced water	
Landtake	40a	Optimisation from an environmental perspective, i.e. the number of wells, pad density and pad spacing	
	7	Cumulative effects (e.g. air pollution, traffic impacts, water resource requirements) of gas play development assessed in planning and permitting taking into account other (non-unconventional gas) developments and plans	
	N13	Member States carry out SEA to set up plans/programmes setting the framework for unconventional gas projects before granting concessions for unconventional gas exploration and production and assess environmental effects of such plans. Assessment	

Aspect	Measure ref.	Description	Sub-measure description
		to address surface aspects such as water abstraction, waste treatment and disposal, transport, air quality, landtake, species diversity as well as known underground risks. Assessment to be reviewed before production commences on the basis of information obtained during the exploration phase. Those MS that have already granted concessions to perform such an assessment without undue delay.	
Visual impact	N15	Mandatory EIA for all projects expected to involve hydraulic fracturing, before exploration starts	
	N16 i	Mandatory EIA (i) after initial phase of well exploration and before first test fracturing	Mandatory EIA according to Directive 2011/92/EU after well exploration and before first test fracturing
	N16 ii	Mandatory EIA (ii) before production commences	Mandatory EIA according to Directive 2011/92/EU before production commences
	N17	Assessment of whether full project is likely to have significant effects on the environment during prospecting phase (i.e. extending the existing requirement in relation to deep drillings under the EIA Directive to include screening prior to development of exploration plans and taking account of the entire project)	
Groundwater contamination	N44	Competent authorities compile regional maps of underground resources	
	N55	Conduct 2D seismic survey to identify faults and fractures.	
	28d	Sharing of information to ensure that all operators in a gas play are aware of risks and can therefore plan	
	N45	Members States establish a capability to address groundwater contamination arising from unconventional gas operations. In the case of transboundary aquifers, joint capability established	
	55g	Engagement with third parties (e.g. regulators, other operators, researchers) to ensure fully aware of any issues / proximity (e.g. to other underground activities)	
	22d	Search for and document potential leakage pathways (e.g. other wells, faults, mines)	
	26d	Development of a conceptual model of the zone before work commences covering geology, groundwater flows, pathways, microseismicity and subsequent updating of the model as information becomes available	Related to 3a x-a4 (which is Low Ambition)
	26e	Modelling of fracturing programme to predict extent of fracture growth based on best information	
	26g	Implementation of remedial measures if well failure occurs	
	55c	Ground motion prediction models to assess the potential impact of induced earthquakes	
	N09	Operator to develop and maintain a contingency plan to address foreseeable impacts of operating conditions on environmental risk management (e.g. degradation of well barriers, casing/cementing as per measure 22)	
	N05	Initiate immediate flowback post fracturing	

Aspect	Measure ref.	Description	Sub-measure description
	N46	The European Commission develops criteria/guidance for underground risk assessment (such as criteria to assess potential risks of groundwater contamination and induced seismicity) related to unconventional gas	
	N07	Operator to use alternative fracturing fluids to water (e.g. nitrogen, CO2, propane)	
	55h	Smaller preinjection prior to main operations to enable induced seismicity response to be assessed	
	22a	Key elements to maintain well safety such as: • blowout preventers • pressure & temperature monitoring and shutdown systems • fire and gas detection • continuous monitoring for leaks and release of gas and liquids • modelling to aid well/HF design • isolate underground source of drinking water prior to drilling • ensure micro-annulus is not formed • casing centralizers to centre casing in hole • select corrosive resistant alloys and high strength steel • fish back casing • maintain appropriate bending radius • triple casing • casing and cementing designed to sustain high pressure and low magnitude seismicity • isolation of the well from aquifers • casings: minimum distance the surface casing extends below aquifer (e.g. 30m below the deepest underground source of drinking water encountered while drilling the well, ref. Environment Agency 2012) and surface casing cemented before reaching depth of e.g. 75m below underground drinking water (ref. AEA 2012). Production casing cemented up to at least 150 metres above the formation where hydraulic fracturing will be carried out (ref. AEA 2012)	
	22b i	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	i) wireline logging (calliper, cement bond, variable density)
	22b ii	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing
	22b iii	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	iii) mechanical integrity testing of equipment (MIT)

Aspect	Measure ref.	Description	Sub-measure description
	22b iv	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	iv) casing inspection test and log
	22c	Multiple barriers between the target formation and people/the environment, including minimum vertical distance between target formation and aquifers	
	26f	Monitoring and control during operations to ensure hydraulic fractures / pollutants do not extend beyond the gas-producing formations and does not result in seismic events or damage to buildings/installations that could be the result of fracturing	
	3a xi	Site baseline Establish the presence of methane in groundwater, including drinking water	
	55d	Microseismicity monitoring and management requirements during operations	LOW AMBITION Real time monitoring of microseismicity during all operations
	55d	Microseismicity monitoring and management requirements during operations	HIGH AMBITION AS LOW plus cessation of fracturing if specified induced seismic activity is detected (using traffic light system)
	3a iii	Site baseline Undertake sampling of groundwater	HIGH AMBITION Sampling of shallow groundwater during wet and dry periods
	3a iii	Site baseline Undertake sampling of groundwater	VERY HIGH AMIBITION Borehole to sample deep groundwater and characterise the hydrological series
	3a x-a1	Site baseline Geological, hydrogeological and seismic conceptual model [1] Obtain and analyse seismic (earthquake) history.	
	3a x-a2	Site baseline Geological, hydrogeological and seismic conceptual model [2] Obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures	LOW AMBITION. Undertake desk study based on existing data and literature
	3a x-a2	Site baseline Geological, hydrogeological and seismic conceptual model [2] Obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures	HIGH AMBITION. In addition LOW obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures through new cores and stratigraphic tests.
	3a x-a3	Site baseline Geological, hydrogeological and seismic conceptual model [3] Undertake surface microseismic survey	

Aspect	Measure ref.	Description	Sub-measure description
	3a x-a4	Site baseline Geological, hydrogeological and seismic conceptual model [4] Undertake complex modelling of fluid flows and migration (reservoir simulations)	LOW AMBITION. Modelling over 100 years
	3a x-a4	Site baseline Geological, hydrogeological and seismic conceptual model [4] Undertake complex modelling of fluid flows and migration (reservoir simulations)	HIGH AMBITION. Modelling is done over 10,000 years
	3a x-a5	Site baseline Geological, hydrogeological and seismic conceptual model [5] Develop maps and cross sections of local geologic structure	
	3a x-a6	Site baseline Geological, hydrogeological and seismic conceptual model [6] Conduct 3D seismic survey to identify faults and fractures	
	3a x-a7	Site baseline Geological, hydrogeological and seismic conceptual model [7] Obtain data on area, thickness, capacity, porosity and permeability of formations.	
	3a xiii	Site baseline Undertake assessment of existing underground wells and structures	LOW AMBITION. Undertake assessment of underground wells and structures
	3a xiii	Site baseline Undertake assessment of existing underground wells and structures	HIGH AMBITION. As LOW AMBITION plus undertake assessment of underground wells and structures desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells
	3b iii	Monitoring Undertake monitoring of groundwater	LOW AMBITION Sampling of shallow groundwater during wet and dry periods
	3b iii	Monitoring Undertake monitoring of groundwater	HIGH AMBITION Deep groundwater sampling network to determine the characteristics of deep groundwater and formation water and piezometric levels
	3b xvii	Monitoring Undertake monitoring of induced seismicity from fracturing	
	3b xviii	Monitoring Undertake monitoring for presence of methane seepages in groundwater, including drinking water.	

Appendix C
Potential Criteria for Categorisation of CFF and UFF

For detailed illustrative concession parameter values, refer to Appendix A.

Criteria	Possible options for legislative provision	Principal Relevant Risks and Impacts	UFF Criteria Characteristics				Comment
			Shale Gas	Tight Gas	Tight Oil	CBM	
Depth	Set a minimum depth above which regulation applies e.g. 1,000 m	Shallower activities may pose greater risk of groundwater pollution	Typically deep	Typically deep	Typically deep	Shallower than other UFFs	Will capture CBM but unlikely to capture other UFF
Depth	Set a minimum depth below which regulation applies e.g. 2,000 m	Deeper activities may pose greater risk to well integrity and associated impacts such as groundwater pollution	Typically deep	Typically deep	Typically deep	Shallower than other UFFs	Unlikely to capture CBM May capture tight oil / tight gas and CFF
Pressure applied during hydraulic fracturing (HF)	Set a pressure used in HF above which regulation applies	Higher pressure = increased potential for compromising well integrity, risk of leaks and induced seismic activity	700 to 1400 bar	Around 690 bar	Around 550 bar	Around 200 bar	Pressure is a function of depth and extent of fracturing required. May capture CFF (typically 500-650 bar) particularly if deep. Unlikely to capture CBM
Need for horizontal drilling	Regulate all activities requiring horizontal drilling	None specific to the technique	Required for shale gas	Required for tight gas	Required for tight oil	Not always used	Horizontal drilling increasingly used in CFF
Use of proppant	Regulate all activities that use proppant	None – proppants are inert	Required for shale gas	Required for tight gas	Required for tight oil	Not always required for CBM	Proppants used for all UFF but not always for CBM. Proppants are inert and not a risk driver
Use of hydraulic fracturing (HF)	Regulate all HF activities	Groundwater pollution, induced seismic, water resource depletion, wastewater management and treatment	Required for shale gas	Required for tight gas	Required for tight oil	Not always used	Will capture CFF where HF used. May not capture CBM

Criteria	Possible options for legislative provision	Principal Relevant Risks and Impacts	UFF Criteria Characteristics				Comment
			Shale Gas	Tight Gas	Tight Oil	CBM	
Volume of water used in HF	Regulate all HF using more than a particular volume of water	Increased risk of leaks, contamination and induced seismicity, water resources depletion	Large volumes (1,000s m^3) typically used	Lower than shale gas	Lower than shale gas	HF not always used. Volumes used less than other UFFs	May not capture tight gas or CBM. Should avoid CFF if set at a sufficiently high volume
Volume of flowback	Regulate all HF generating more than a particular volume of flowback	Increased wastewater treatment requirements	Large volumes (1,000s m^3) typically generated	Lower than shale gas	Lower than shale gas	HF not always used. Flowback volumes less than other UFF	% flowback is a factor of volume injected and formation characteristics. May not capture all operations, particularly CBM. Should avoid CFF
Volume of produced water	Regulate all HF generating more than a particular volume of produced water	Increased wastewater treatment requirements, water resources depletion	Small volumes generated per well but large volumes across a field	Similar to shale gas	Similar to shale gas	Higher than shale gas per well	Rate of water production is a function of the formation and is variable. CBM involves active pumping. Produced water quality is variable
Proximity to groundwater resource	Regulate all HF activities that take place in or in proximity to a groundwater resource	Groundwater resource pollution	Takes place in low permeability deposits, not in proximity to groundwater resources	Typically more water (groundwater) present in reservoir than shale gas. Takes place not in proximity to groundwater resources	Typically more water (groundwater) present in reservoir than shale gas. Takes place not in proximity to groundwater resources	Typically more groundwater present in CBM and is in greater proximity to ground water resources than other UFFs	Groundwater as per Directive 2000/60/EC, 'all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil'. No differentiation between groundwater that is potable vs deep saline groundwater
Number / density of wells	Regulate developments above a particular scale (where size is	Cumulative impacts (groundwater pollution / emissions to air /	Development size may vary considerably	Development size may vary considerably	Development size may vary considerably.	Potentially lower (generally	May capture CFF using Enhanced Oil Recovery.

Criteria	Possible options for legislative provision	Principal Relevant Risks and Impacts	UFF Criteria Characteristics				Comment
			Shale Gas	Tight Gas	Tight Oil	CBM	
	determined by number / density of wells)	surface water pollution / traffic)			Potentially lower (generally smaller schemes)	smaller schemes)	

Appendix D
Measures Included in Policy Options

Non-BAU Measures in Policy Options

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Zoning	N/A	42b	42b	1	-	Location of sites close to existing pipeline infrastructure	0	Site selection takes into consideration existing gas pipeline infrastructure to enable minimisation of the need for additional pipeline infrastructure and associated development impacts	Qual	LL	No	1	-	1	-	1
Zoning	N/A	N48	N48	2	-	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers and the surface to be determined based on risk assessment	0	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	26c	26c	3	-	Fracturing to be a minimum distance from water resources	0	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	40c	40c	4	-	High land, agricultural and ecological value locations avoided	0	Assessment of and avoidance of high land, agricultural and ecological value locations (e.g. Natura 2000 sites, conservation sites).	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	5	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Buffer zone from abstraction points and aquifers of 1,000m for drinking water related abstraction	Applicable regardless of area type (i.e. not limited to Natura 2000 site and other specified sites). Hence applicability is broader.	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	6	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Buffer zone from residential areas, schools hospitals and other sensitive areas of 1,600m	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	7	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Buffer zone within which detailed noise assessment is required of 305m	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	8	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Buffer zone from abandoned wells and other potential pathways for fluid migration (distance specified on risk basis)	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	9	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Additional containment for sites near surface water supply locations	This is required for sites within 800m of water supply locations in Colorado. The definition of additional containment is not provided - assume bunded tanks/site - see other measures re. this in surface water	Qual	MM	No	1	-	1	-	1
Zoning	N/A	40a	40a	10	-	Optimisation from an environmental perspective, i.e. the number of wells, pad density and pad spacing	0	Optimise the number of wells per pad, pad density and pad spacing to minimise cumulative environmental impacts (e.g. one pad per 2.6 km2 proposed by New York State). This will include consideration of siting with consideration of conflicts with nearby or adjacent sensitive land uses such as residences, schools, hospitals, available transport infrastructure, access to water supply, access to wastewater treatment, etc. Note: the acquis communautaire requires this measure, but it is	Qual	HM	No	1	-	1	-	1
Zoning	N/A	40b	40b	11	-	Compatibility with current and future potential landuse (Natura 2000 sites, conservation sites, human use, industrial use, appropriate zoning, CCS, geothermal, water abstraction)	0	Assessment of compatibility with current and future landuse plans (e.g. Natura 2000 sites, conservation sites, human use, industrial use, appropriate zoning. Note: the acquis communautaire requires this measure, notably as a mitigation measure under the SEAD/the EIAD, but without guarantee of the result, Natura2000 Directives	Qual	HM	No	1	-	1	-	1
Zoning	N/A	1b	1b	12	-	Restrict operations within and underneath specified sites (e.g. Natura 2000, protected sites, coal mining areas, drinking water protection areas, water extraction areas for public drinking water supply, mineral spa protection zones karstic aquifers, flood prone zones and mineral water reserves, reforestation areas and areas known to be unfavourable - with regard to potential environmental impacts) or within certain distances to specified sites	0	Operations would be restricted (i.e. greater controls as required by discretion of MS authorities) within specified areas. Areas known to be unfavourable - with regard to potential environmental impacts - geological and hydrogeological conditions (groundwater potentials and pathways, tectonically fractured rocks, artesian confined aquifers, suspected pathways introduced by abandoned boreholes	Qual	HM	Yes	1	-	1	-	1
Zoning	N/A	55e	55e	13	-	Avoid high seismicity risk areas	0	0	Qual	HH	No	1	-	1	-	1
Zoning	N/A	55i	55i	14	-	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers (e.g. 600m) and the surface (e.g. 600m depth requires special permit)	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers of, e.g. 600m	0	Qual	HH	No	1	-	1	-	1
Zoning	N/A	55i	55i	15	-	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers (e.g. 600m) and the surface (e.g. 600m depth requires special permit)	Special permit conditions where hydraulic fracture pipes are less than, e.g. 600m depth from surface	0	Qual	HH	No	1	-	1	-	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	**Sub**	**Measure ref.**		**Order**	**LOW vs. HIGH**	**Measure**	**Sub-measure description**	**Further definition**	**Quant/ qual**	**LoA rating**		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Zoning	N/A	1a	1a	16	-	Prohibit operations within and underneath specified sites (e.g. Natura 2000, protected sites, coal mining areas, drinking water protection areas, water extraction areas for public drinking water supply, mineral spa protection zones karstic aquifers, flood prone zones and mineral water reserves, reforestation areas and areas known to be unfavourable - with regard to potential environmental impacts) or within certain distances to specified sites	0	Areas known to be unfavourable - with regard to potential environmental impacts - geological and hydrogeological conditions (groundwater potentials and pathways, tectonically fractured rocks, artesian confined aquifers, suspected pathways introduced by abandoned boreholes or mining activities)	Qual	HH	Yes	1	-	1	-	1
Underground Risks	N/A	N44	N44	17	-	Competent authorities compile regional maps of underground resources	0	0	Qual	LL	No	1	-	1	-	1
Underground Risks	N/A	N55	N55	18	-	Conduct 2D seismic survey to identify faults and fractures.	0	0	Quant	LM	Yes	1	1	1	1	1
Underground Risks	N/A	28d	28d	19	-	Sharing of information to ensure that all operators in a gas play are aware of risks and can therefore plan	0	0	Qual	LM	Possible - low	1	1	1	1	1
Underground Risks	N/A	N45	N45	20	-	Members States establish a capability to address groundwater contamination arising from unconventional gas operations. In the case of transboundary aquifers, joint capability established	0	0	Qual	LM	No	1	-	1	-	1
Underground Risks	N/A	55g	55g	21	-	Engagement with third parties (e.g. regulators, other operators, researchers) to ensure fully aware of any issues / proximity (e.g. to other underground activities)	0	0	Qual	ML	Possible - low	1	-	1	-	1
Underground Risks	N/A	22d	22d	22	-	Search for and document potential leakage pathways (e.g. other wells, faults, mines)	0	Through delivery of 3 a x detail	Quant	MM	Possible - high	1	1	1	1	1
Underground Risks	N/A	26d	26d i	23	L	i) Development of a conceptual model of the zone before work commences covering geology, groundwater flows, pathways, microseismicity and subsequent updating of the model as information becomes available ii) as above plus Modelling of the impact of groundwater pumping on linked groundwater and surface water flows and quality	Related to 3a x-a4 (which is Low Ambition)	Through delivery of 3 a x detail	Quant	MM	No	1	1	1	1	1
Underground Risks	N/A	26e	26e	25	-	Modelling of fracturing programme to predict extent of fracture growth based on best information	0	Application of Discrete Fracture Network (DFN) approach including dynamic response (e.g. hydro-shearing), Finite Element Analysis (FEA) or Discrete Element Method (DEM). 3D fracture modelling integrated with geomechanics modelling	Quant	MM	No	1	-	1	1	1
Underground Risks	N/A	26g	26g	26	-	Implementation of remedial measures if well failure occurs	0	0	Qual	MM	Yes	1	1	1	1	1
Underground Risks	N/A	55c	55c	27	-	Ground motion prediction models to assess the potential impact of induced earthquakes	0	0	Quant	MM	No	-	-	-	-	-
Underground Risks	N/A	N09	N09	28	-	Operator to develop and maintain a contingency plan to address foreseeable impacts of operating conditions on environmental risk management (e.g. degradation of well barriers, casing/cementing as per measure 22)	0	0	Quant	MM	No	-	-	-	1	1
Underground Risks	N/A	N05	N05	29	-	Initiate immediate flowback post fracturing	0	0	Qual	MM	No	1	1	1	-	1
Underground Risks	N/A	N46	N46	30	-	The European Commission develops criteria/guidance for underground risk assessment (such as criteria to assess potential risks of groundwater contamination and induced seismicity) related to unconventional gas	0	0	Qual	MH	No	-	-	-	-	-
Underground Risks	N/A	N07	N07	31	-	Operator to use alternative fracturing fluids to water (e.g. nitrogen, CO2, propane)	0	0	Qual	MH	No	-	-	-	-	-
Underground Risks	N/A	55h	55h	32	-	Smaller preinjection prior to main operations to enable induced seismicity response to be assessed	0	Mini-fractures area carried out prior to full scale fracturing. Monitoring of the seismic response to the mini-fractures is carried out and assessment of the location's actual response compared with the modelled response is made. Analysis of results and conclusion drawn regarding suitability of and approach to full scale operations. Enables model predictions to be verified and the actual response of geological formations to be assessed.	Qual	MH	No	1	-	1	-	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Underground Risks	N/A	22a	22a	33	-	Key elements to maintain well safety such as: • blowout preventers • pressure & temperature monitoring and shutdown systems • fire and gas detection • continuous monitoring for leaks and release of gas and liquids • modelling to aid well/HF design • isolate underground source of drinking water prior to drilling • ensure micro-annulus is not formed • casing centralizers to centre casing in hole • select corrosive resistant alloys and high strength steel • fish back casing • maintain appropriate bending radius • triple casing • casing and cementing designed to sustain high pressure and low magnitude seismicity • isolation of the well from aquifers • casings: minimum distance the surface casing extends below aquifer (e.g. 30m below the deepest underground source of drinking water encountered while drilling the well, ref. Environment Agency 2012) and surface casing cemented before reaching depth of e.g. 75m below underground drinking water (ref. AEA 2012). Production casing cemented up to at least 150 metres above the formation where hydraulic	0	Measures to be split out for cost purposes	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b i	34	-	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	i) wireline logging (calliper, cement bond, variable density)	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b ii	35	-	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b iii	36	-	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	iii) mechanical integrity testing of equipment (MIT)	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b iv	37	-	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	iv) casing inspection test and log	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22c	22c	38	-	Multiple barriers between the target formation and people/the environment, including minimum vertical distance between target formation and aquifers	0	0	Qual	HH	No	1	1	1	-	1
Underground Risks	N/A	26f	26f	39	-	Monitoring and control during operations to ensure hydraulic fractures / pollutants do not extend beyond the gas-producing formations and does not result in seismic events or damage to buildings/installations that could be the result of fracturing	0	Linked to 3 b xvii	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3a	3a xi	40	-	Site baseline Establish the presence of methane in groundwater, including drinking water	0	0	Quant	MM	Yes	1	1	1	1	1
Underground Risks	N/A	55d	55d	41	L	Microseismicity monitoring and management requirements during operations	LOW AMBITION Real time monitoring of microseismicity during all operations	Linked to 3 b xvii	Quant	MM	No	-	1	1	1	1
Underground Risks	N/A	55d	55d	42	-	Microseismicity monitoring and management requirements during operations	HIGH AMBITION AS LOW plus cessation of fracturing if specified induced seismic activity is detected (using traffic light system)	0	Qual	HH	No	1	1	1	1	1

Categorisation		Measure info										Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating			1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Underground Risks	N/A	3a	3a iii	43	L	Site baseline Undertake sampling of groundwater	MEDIUM AMBITION Sampling of shallow groundwater during wet and dry periods (cost is shown in Middle Ambition column)	Concentrate boreholes near pad (as on impacts on groundwater due to surface spills greatest near pad). Boreholes, at 15m depth at each corner. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals.	Quant	MM		Yes	-	-	-	-	-
Underground Risks	N/A	3a	3a iii	44	H	Site baseline Undertake sampling of groundwater	HIGH AMIBITION Borehole to sample deep groundwater and characterise the hydrological series (cost is shown in High Ambition column)	Deep boreholes in area. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals.	Quant	HH		Possible - low	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a1	45	-	Site baseline Geological, hydrogeological and seismic conceptual model [1] Obtain and analyze seismic (earthquake) history.	0	0	Quant	HH		No	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a2	46	L	Site baseline Geological, hydrogeological and seismic conceptual model [2] Obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures	LOW AMBITION. Undertake desk study based on existing data and literature	0	Quant	MH		Yes	-	-	-	-	-
Underground Risks	N/A	3a	3a x-a2	47	H	Site baseline Geological, hydrogeological and seismic conceptual model [2] Obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures	HIGH AMBITION. In addition LOW obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures through new cores and stratigraphic tests	0	Quant	HH		No	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a3	48	-	Site baseline Geological, hydrogeological and seismic conceptual model [3] Undertake surface microseismic survey	0	0	Quant	HH		No	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a4	49	L	Site baseline Geological, hydrogeological and seismic conceptual model [4] Undertake complex modelling of fluid flows and migration (reservoir simulations)	LOW AMBITION. Modelling over 100 years	0	Quant	MH		No	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a4	50	H	Site baseline Geological, hydrogeological and seismic conceptual model [4] Undertake complex modelling of fluid flows and migration (reservoir simulations)	HIGH AMBITION. Modelling is done over 10,000 years	0	Quant	HH		No	-	-	-	-	-
Underground Risks	N/A	3a	3a x-a5	51	-	Site baseline Geological, hydrogeological and seismic conceptual model [5] Develop maps and cross sections of local geologic structure	0	0	Quant	HH		Possible - low	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a6	52	H	Site baseline Geological, hydrogeological and seismic conceptual model [6] Conduct 3D seismic survey to identify faults and fractures	0	0	Quant	HH		Possible - low	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a7	53	-	Site baseline Geological, hydrogeological and seismic conceptual model [7] Obtain data on area, thickness, capacity, porosity and permeability of formations	0	0	Quant	HH		Possible - high	1	1	1	1	1
Underground Risks	N/A	3a	3a xiii	54	L	Site baseline Undertake assessment of existing underground wells and structures	LOW AMBITION. Undertake assessment of underground wells and structures	Develop list of penetrations into zone within area (from well history databases).	Quant	MH		Possible - high	-	-	-	-	-
Underground Risks	N/A	3a	3a xiii	55	H	Site baseline Undertake assessment of existing underground wells and structures	HIGH AMBITION. As LOW AMBITION plus undertake assessment of underground wells and structures desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells	0	Quant	HH		No	1	1	1	1	1
Underground Risks	N/A	3b	3b iii	56	L	Monitoring Undertake monitoring of groundwater	MEDIUM AMBITION Sampling of shallow groundwater during wet and dry periods	Concentrate boreholes near pad (as on impacts on groundwater due to surface spills greatest near pad). Boreholes, at 15m depth at each corner. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals.	Quant	MM		Yes	-	-	-	-	-
Underground Risks	N/A	3b	3b iii	57	H	Monitoring Undertake monitoring of groundwater	HIGH AMBITION Deep groundwater sampling network to determine the characteristics of deep groundwater and formation water and piezometric levels	Deep boreholes network in area. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals.	Quant	HH		No	1	1	1	1	1
Underground Risks	N/A	3b	3b xvii	58	-	Monitoring Undertake monitoring of induced seismicity from fracturing	0	0	Quant	HH		No	1	1	1	1	1
Underground Risks	N/A	3b	3b xviii	59	-	Monitoring Undertake monitoring for presence of methane seepages in groundwater, including drinking water.	0	0	Quant	HH		Possible - low	-	-	-	-	-

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	**Sub**	**Measure ref.**		**Order**	**LOW vs. HIGH**	**Measure**	**Sub-measure description**	**Further definition**	**Quant/ qual**	**LoA rating**		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Chemical Use	N/A	CSL5	CSL5	60	-	Authorities to organise an exchange of views/information on environmentally safer technologies and alternatives to the use of chemicals in hydraulic fracturing	0	0	Qual	LL	No	1	-	1	-	1
Chemical Use	N/A	N24	N24	61	-	Traceability of chemicals used by an operator	0	0	Qual	LL	No	-	-	-	-	-
Chemical Use	N/A	CAL1	CAL1	62	-	CSA/risk assessment explicitly specific to hydraulic fracturing in the EU to be included in REACH Registration	Chemicals - assessment	Cost to be estimated based on existing data in #11.	Quant	ML	No	-	-	-	-	-
Chemical Use	N/A	CAL2	CAL2	63	-	Develop a peer-reviewed EU-level exposure scenario / SpERC for HF for different chemical types	Chemicals - assessment	Estimated cost of developing SpERC to similar level of detail to those that already exist for e.g. additives used in petroleum products (CONCAWE/ESIG) http://www.cefic.org/Industry-support/Implementing-reach/Guidances-and-Tools1/	Quant	ML	No	1	-	1	-	1
Chemical Use	N/A	CAL3	CAL3	64	-	CAL2 to be implemented in CSAs for chemicals used in HF and any deviations explained	Chemicals - assessment	Should be feasible to estimate additional cost of UG company doing their own CSA for this specific use for typical number of chemicals used	Quant	ML	No	1	-	1	-	1
Chemical Use	N/A	CDL1	CDL1	65	-	Disclosure of information to Competent Authority: declaration of substance name and CAS number for the chemical substances potentially to be used in hydraulic fracturing. Per concession/play	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity)	Qual	ML	No	1	-	1	1	1
Chemical Use	N/A	CDL2	CDL2	66	-	Disclosure of information to the public: list of chemicals potentially to be used in hydraulic fracturing by UG company to be made available (e.g. via company website or centralised data dissemination portal). Per concession/play	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity)	Qual	ML	Possible - high	1	-	1	1	1
Chemical Use	N/A	CSL1a	CSL1a	67	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A or 1B	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL1b	CSL1b	68	-	Non-use in biocidal products of any substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A or 1B	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL1c	CSL1c	69	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as aquatic acute category 1 or aquatic chronic category 1	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL1d	CSL1d	70	-	Non-use in biocidal products of any substances with [harmonised or notified] classification as aquatic acute category 1 or aquatic chronic category 1	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL2	CSL2	71	-	Non-use of any substances on REACH Candidate List for authorisation (substances of very high concern)	Chemicals - selection	Too many substances potentially used in HF to robustly estimate differences in costs. Impacts on well productivity will far outweigh differences in prices of fluid additives	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL3	CSL3	72	-	Negative list of named substances that must not be used in UG extraction (alternative to two measures CSL1 and CSL2)	Chemicals - selection	Partially quantitative. Potential to cost actually developing the list but costs of not using substances on that list not quantifiable as per measures above	Quant	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL4	CSL4	73	-	Demonstration that all steps practicable have been taken to reduce number, concentration and volume of chemicals used in hydraulic fracturing	Chemicals - selection	Not considered feasible to quantify costs as too site-specific.	Qual	ML	No	1	1	1	1	1
Chemical Use	N/A	CSM4	CSM4	74	-	Establish general principles for the use of chemicals (minimise use, substitution by less hazardous substances), oblige operator to present and discuss alternative substances and establish third party verification.	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CAM1	CAM1	75	-	Chemical safety assessment / biocide risk assessment includes assessment of risks of potential transformation products in HF / underground context, as part of permit/licence, with risk management measures implemented accordingly	Chemicals - assessment	Could be e.g. 2-3 times cost for standard CSA / risk assessment?	Quant	MM	No	-	-	-	-	-
Chemical Use	N/A	CSM2	CSM2	76	-	Positive list of substances expected to be safe under EU UG extraction conditions and require operators to only use substances on this positive list	Chemicals - selection	Partially quantitative. Potential to cost actually developing the list but costs of only using substances on that list not quantifiable as per measures above	Quant	MM	No	1	1	1	1	1
Chemical Use	N/A	CSM3	CSM3	77	-	Selection of substances (chemicals and proppants) that minimise the need for treatment when present in flowback water	Chemicals - selection	Not considered feasible to quantify costs as insufficient data on which substances (from a very large list) require more/less treatment under different circumstances	Qual	MM	No	1	1	1	1	1
Chemical Use	N/A	3b	3b x	78	-	Monitoring Undertake monitoring of chemicals type and volume used including record keeping	0	0	Quant	MM	Possible - low	1	-	1	1	1
Chemical Use	N/A	CSM1a	CSM1a	79	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A, 1B or 2	Chemicals - selection	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A, 1B or 2	Qual	LH	No	1	1	1	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Chemical Use	N/A	CSM1 b	CSM1b	80	-	Non-use in biocidal products of any substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A, 1B or 2	Chemicals - selection	Non-use in biocidal products of any substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A, 1B or 2	Qual	LH	No	1	1	1	1	1
Chemical Use	N/A	CSM1 c	CSM1c	81	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as aquatic acute category 1 or 2 or aquatic chronic category 1 or 2	Chemicals - selection	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as aquatic acute category 1 or 2 or aquatic chronic category 1 or 2	Qual	LH	No	1	1	1	1	1
Chemical Use	N/A	CSM1 d	CSM1d	82	-	Non-use in biocidal products of any substances with [harmonised or notified] classification as aquatic acute category 1 or 2 or aquatic chronic category 1 or 2	Chemicals - selection	Non-use in biocidal products of any substances with [harmonised or notified] classification as aquatic acute category 1 or 2 or aquatic chronic category 1 or 2	Qual	LH	No	1	1	1	1	1
Chemical Use	N/A	CDM1	CDM1	83	-	Disclosure of information to Competent Authority: declaration of substance name, CAS number, precise concentrations, quantities and all physicochemical and (eco)toxicological data for the substances potentially to be used in hydraulic fracturing. Also potentially e.g. date of fracturing, total volume of fluids, type and amount of proppant; description of the precise additive purpose; concentration in the total volume. Per well. Prior to and after operations	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity)	Qual	HL	Possible - high	1	-	1	1	1
Chemical Use	N/A	CDM2	CDM2	84	-	Disclosure of information to public: list of chemicals and CAS numbers used to be made available (e.g. via company website and centralised data dissemination portal) for the chemicals potentially to be used in hydraulic fracturing. Per concession/play. Prior to and after operations	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity)	Qual	HL	No	1	-	1	1	1
Chemical Use	N/A	N26	N26	85	-	Select proppants which minimise the HVHF treatment required	0	0	Qual	MH	No	1	1	1	1	1
Chemical Use	N/A	CAH1	CAH1	86	-	Chemical safety assessment / biocide risk assessment includes assessment of risks of mixtures of chemicals used in HF as part of permit/licence, with risk management measures implemented accordingly. To include potential additive or synergistic impacts	Chemicals - assessment	Scientifically challenging and not likely to be possible to quantify with any degree of certainty.	Qual	HM	No	-	-	-	-	-
Chemical Use	N/A	CDH1	CDH1	87	-	Disclosure of information to public: details of substance name, CAS number, concentrations, and all physicochemical and (eco)toxicological data for the substances potentially to be used in hydraulic fracturing. This is to be made available (e.g. via company website and centralised data dissemination portal). Also potentially e.g. date of fracturing, total volume of fluids, type and amount of proppant; description of the overall purpose of the additives; concentration in the total volume. Per well. Prior to and after operations	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity).	Qual	HM	Possible - low	1	-	1	1	1
Chemical Use	N/A	CSH2 a	CSH2a	88	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification for any health or environmental effects	Chemicals - selection	0	Qual	MH	No	1	1	1	1	1
Chemical Use	N/A	CSH2 b	CSH2b	89	-	Non-use in biocidal products of any substances with [harmonised or notified] classification for any health or environmental effects	Chemicals - selection	0	Qual	MH	No	1	1	1	1	1
Chemical Use	N/A	CSH1	CSH1	90	-	Use of water or inert materials only in hydraulic fracturing	Chemicals - selection	Not thought to be practicable and likely to have significant impact on viability and productivity of UG extraction. Not considered practical to quantify costs - main impact will be on well productivity, maintenance frequency, etc.	Qual	HH	No	1	1	1	1	1
Water Depletion	N/A	38a	38a i	91	-	i) Notification of water demand from fracturing operations to relevant water utilities and competent authorities	0	Inform relevant authorities (i.e. water utilities, environmental regulators, planning authorities) of water demand for the lifetime of the project.	Qual	LM	No	1	1	1	1	1
Water Depletion	N/A	38b	38b	93	-	Demand profile for water	0	Establish the water demand pattern taking account of number of wells, pad locations, drilling sequence, water consumption per unit operation. Establish flow patterns including peak and average flow volumes under a variety of scenarios	Quant	LM	Possible - high	1	-	1	1	1
Water Depletion	N/A	N49	N49	94	-	Strategic planning and staged approach of play development to avoid peaks in water demand	0	0	Qual	MM	No	1	-	1	-	1
Water Depletion	N/A	38c	38c	95	-	Water management plan	0	Develop a water management plan to cover water supply and efficient use on site.	Qual	MM	Possible - high	1	1	1	1	1
Water Depletion	N/A	3a	3a vi	96	-	Site baseline Establish water source availability and test for suitability	0	Locate water sources and identifying availability, water rights. Test water sources for suitability	Quant	MM	Possible - high	1	-	1	1	1
Water Depletion	N/A	3b	3b vi	97	-	Monitoring Water resources availability	0	0	Quant	MM	No	1	-	1	1	1
Water Depletion	N/A	3b	3b ix	98	-	Monitoring Undertake monitoring of water volumes and origin	0	0	Quant	MM	No	1	-	1	1	1
Water Depletion	N/A	38d	38d	99	-	Reuse of flowback and produced water for fracturing	0	Reuse flowback and/or produced water to make up fracture fluid.	Quant	MM	No	1	-	1	1	1
Water Depletion	N/A	38e	38e	100	-	Use of lower quality water for fracturing (e.g. non-potable ground / surface water, rainwater harvesting, saline aquifers, sea water, treated industrial waterwaters)	0	Use lower quality water (non-potable) to make up fracture fluid.	Qual	MM	No	1	1	1	-	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Surface Water	N/A	33i	33i	101	-	Good site security	0	Operators would be required to ensure that the site is protected properly to prevent vandalism that may lead to pollution from damaged equipment/infrastructure	Quant	ML	Yes	-	-	-	-	-
Surface Water	N/A	29a	29a	102	-	Good practice construction / deconstruction practices, including design for well abandonment	0	Note - also included in post closure ref. demolition. Operators should apply construction industry good practice to prevent pollution of surface water through operator training and approach to construction practice	Qual	MM	Possible - high	1	1	1	1	1
Surface Water	N/A	33a	33a	103	-	Good site practice to prevention of leaks and spills	0	0	Qual	MM	Yes	1	1	1	1	1
Surface Water	N/A	33d	33d	104	-	Spill kits available for use	0	0	Quant	MM	Yes	1	1	1	1	1
Surface Water	N/A	3a	3a ii	105	H	Site baseline Undertake sampling of surface water bodies in wet and dry periods	High Ambition	Analyse for suspended solids, BOD, dissolved oxygen, pH, ammonia, chloride also total petroleum hydrocarbons and polyaromatic hydrocarbons, radioactivity, fracturing chemicals and heavy metals for assurance.	Quant	MM	Possible - low	1	1	1	1	1
Surface Water	N/A	3b	3b ii	106	L	Monitoring Undertake monitoring of surface water bodies in wet and dry periods	LOW AMBITION Monitoring Undertake monitoring of surface water bodies in wet and dry periods	Analyse for suspended solids, BOD, dissolved oxygen, pH, ammonia, chloride also total petroleum hydrocarbons and polyaromatic hydrocarbons, radioactivity, fracturing chemicals and heavy metals for assurance.	Quant	MM	Possible - high	-	1	1	1	1
Surface Water	N/A	3b	3b ii	107	H	Monitoring Undertake monitoring of surface water bodies in wet and dry periods	HIGH AMBITION AS LOW AMBITION with alert system promoting corrective action	0	Quant	MH	No	1	-	1	-	1
Surface Water	N/A	33e	33e	108	-	Berm around site boundary	0	0	Quant	HM	No	1	1	1	-	1
Surface Water	N/A	33g	33g	109	-	Collection and control of surface runoff	0	Operators construct sites to effectively collect and control stormwater, e.g. draining to a single collection point, to enable effective control and management of any spills and leaks.	Quant	MH	Possible - high	1	-	1	1	1
Surface Water	N/A	29c	29c	110	-	Bunding of fuel tanks	0	0	Quant	HH	No	1	-	1	-	1
Surface Water	N/A	30d	30d	111	-	Use of closed tanks for mud storage	0	0	Quant	HH	Possible - low	-	-	-	-	-
Surface Water	N/A	33b	33b	112	-	Use of tank level alarms	0	For chemicals, fracturing fluid, muds and wastewaters. Activation triggers corrective action/contingency plan implementation.	Quant	HH	Possible - high	1	1	1	1	1
Surface Water	N/A	33c	33c	113	H	Use of double skinned closed storage tanks	High Ambition	For chemicals, fracturing fluid, muds and wastewaters	Quant	HH	No	1	1	1	1	1
Surface Water	N/A	33f	33f	114	-	Impervious site liner under pad with puncture proof underlay	0	0	Quant	HH	Yes	1	-	1	1	1
Air Quality	N/A	59d	59d	115	-	Use of vehicles (water, chemicals, waste trucking) that meet minimum air emission standards e.g. EURO standards	0	0	Qual	LL	No	-	-	-	-	-
Air Quality	N/A	N54	N54	116	-	Encourage industry voluntary approach to reduce air pollutants and greenhouse gases	0	0	Qual	LM	No	1	-	1	-	1
Air Quality	N/A	16b	16b i	117	-	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	Low emission power supply (switching to LPG)	0	Quant	LM	No	1	-	1	-	1
Air Quality	N/A	16b	16b ii	118	-	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	Low emission power supply (switching to grid electricity)	0	Quant	LM	No	1	-	1	-	1
Air Quality	N/A	16d	16d	119	-	Application of abatement techniques to minimise emissions (assumed SCR for NOx and Diesel Particulate Filter (DPF) for PM).	0	SCR for NOx Diesel Particulate Filter (DPF) for PM	Quant	LM	No	1	-	1	-	1
Air Quality	N/A	17c	17c	120	L	Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network)	LOW AMBITION Flares or incinerators to reduce emissions from fracturing fluid at exploration stage	Capture gas from fracture fluid at exploration stage and flare or incinerate	Quant	MM	Yes	-	-	-	-	-
Air Quality	N/A	17c	17c	121	H	Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network)	HIGH AMBITION As LOW AMBITION with no audible or visible flaring	0	Quant	MM	No	-	-	-	-	-
Air Quality	N/A	3a	3a i	122	-	Site baseline Undertake sampling of air quality	0	Three month monitoring period to establish baseline using passive monitoring techniques at circa six points in the vicinity of a pad. Monitoring for combustion gasses (NOx, NO2, PM10 and also SO2, CO and VOCs).	Quant	MM	Possible - high	1	1	1	1	1
Air Quality	N/A	3b	3b i	123	-	Monitoring Undertake monitoring of air quality	0	On-going monitoring in the vicinity of a pad. Monitoring for combustion gasses (NOx, NO2, PM10 and also SO2, CO and VOCs).	Quant	MM	Possible - low	1	1	1	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	**Sub**	**Measure ref.**		**Order**	**LOW vs. HIGH**	**Measure**	**Sub-measure description**	**Further definition**	**Quant/ qual**	**LoA rating**		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Air Quality	N/A	16a	16a	124	-	Preparation of an emissions reduction plan (reduced emission completions) including an assessment of potential local air quality impacts including implications for compliance with ambient air quality limit values	0	Plan preparation only Develop emissions inventory for the site Undertake dispersion modelling of inventory to estimate concentrations within site boundaries and surrounding areas Undertake additional modelling of potential impacts of emissions from site on nearby population and/or sensitive habitats Identify and assess options for reducing	Quant	MH	No	1	1	1	1	1
Air Quality	N/A	17b	17b	125	-	Reduced emission completions (REC) to eliminate gas venting: prohibit venting of gas; capture and cleaning for use of gas released from fracture fluid and produced water	0	Capture and cleaning for use of gas released from fracture fluid and produced water	Quant	HH	No	1	1	1	1	1
Waste	N/A	N47	N47	126	-	Operator demonstrates availability of appropriate wastewater treatment facilities	0	0	Qual	LL	No	1	-	1	1	1
Waste	N/A	36c	36c	127	-	Treatment requirements for wastewater and capability of treatment works to treat wastewater established	0	0	Qual	LL	Possible - high	1	1	1	1	1
Waste	N/A	27c	27cii	128	-	Injection of flowback and produced water into designated formations for disposal, provided specific conditions are in place: i) treated waste water and ii) untreated wastewater	Untreated wastewater	0	Qual	LL	Possible - high	-	1	1	1	1
Waste	N/A	N50	N50	129	-	Lined open ponds with safety net protecting biodiversity	0	0	Qual	ML	No	1	1	1	1	1
Waste	N/A	27c	27c i	130	-	Injection of flowback and produced water into designated formations for disposal, provided specific conditions are in place: i) treated waste water and ii) untreated wastewater	Treated wastewater	0	Qual	MM	Possible - high	-	1	1	1	1
Waste	N/A	3b	3b xiii	131	-	Monitoring Undertake monitoring of drilling mud volumes and treatment	0	Analyse for VOCs, metals, total petroleum hydrocarbons, NORM.	Quant	MM	No	1	1	1	1	1
Waste	N/A	3b	3b xiv	132	-	Monitoring Undertake monitoring of flowback water return rate and characterise	0	Analyse for oil & grease, BTEX, VOCs, SVOCs, TDS, pH, sulphates, H2S, heavy metals, NORM, biocides, emulsion breakers, corrosion inhibitors	Quant	MM	Possible - high	1	1	1	1	1
Waste	N/A	3b	3b xv	133	-	Monitoring Undertake monitoring (volume and characterisation) of produced water volume and treatment solution	0	Analyse for oil & grease, BTEX, VOCs, SVOCs, TDS, pH, sulphates, H2S, heavy metals, NORM, biocides, emulsion breakers, corrosion inhibitors	Quant	MM	Possible - high	1	1	1	1	1
Waste	N/A	N53	N53	134	-	Consider wastewaters from unconventional gas operations as hazardous waste	0	0	Qual	MM	No	-	-	-	-	-
Waste	N/A	27f	27f	135	-	Operators keep records of all waste management operations and make them available for inspection (e.g. of flowback, produced water management)	0	0	Qual	LH	No	1	1	1	1	1
Waste	N/A	N51	N51	136	-	Consider wastewaters hazardous unless operator demonstrates otherwise	0	0	Qual	MH	No	1	-	1	-	1
Waste	N/A	N52	N52	137	-	Ban injection of wastewaters into geological formations for disposal	0	0	Qual	MH	No	-	-	-	-	-
Waste	N/A	30c	30c	138	-	Use of closed loop system to contain drilling mud	0	Closed-loop systems employ a suite of solids control equipment to minimise drilling fluid dilution and provide the economic handling of the drilling wastes. The closed loop system can include a series of linear-motion shakers, mud cleaners and centrifuges followed by a dewatering system. The combination of equipment typically results in a "dry" location where a reserve pit is not required, used fluids are recycled, and solid wastes can be land	Quant	HH	Possible - high	1	1	1	-	1
Post Closure	N/A	N22	N22	141	-	Maintain records of well location and depth indefinitely	0	0	Qual	LL	Yes	1	1	1	1	1
Post Closure	N/A	N11	N11	142	-	Operator to provide financial guarantee to competent authority to cover costs of any remedial action following transfer of responsibility	0	Required following transfer of responsibility as prior to that point in time, the operator remains responsible for remedial action.	Qual	LM	No	-	-	-	1	1
Post Closure	N/A	N12	N12	143	-	Operator to provide a financial contribution to the competent authority following closure and abandonment. This contribution should be sufficient to cover ongoing monitoring and related activities over a sufficient period [assume minimum of 20 years]	0	0	Qual	ML	No	-	-	-	1	1
Post Closure	N/A	26g	26g	144	-	Implementation of remedial measures if well failure occurs	0	Note - measure also listed under 'Underground risks'	Qual	MM	Possible - high	1	1	1	1	1
Post Closure	N/A	29a	29a	145	-	Good practice construction / deconstruction practices, including design for well abandonment	0	Note - also included in surface water ref. construction. Operators should apply construction industry good practice to prevent pollution of surface water through operator training and approach to construction practice	Qual	MM	Possible - high	-	1	1	1	1
Post Closure	N/A	N10	N10	146	-	Operator remain responsible for monitoring, reporting and corrective measures following well closure (or temporary well abandonment) and prior to transfer of responsibility to competent authority [assume minimum of 20 years]	0	Transfer of responsibility to occur	Qual	MM	No	-	-	-	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Post Closure	N/A	13d	13d ii	147	-	Abandonment survey Undertake sampling of surface water bodies near the pad	0	Surface water Sampling of surface water courses near the pad and analyse for suspended solids, BOD, dissolved oxygen, pH, ammonia, chloride also total petroleum hydrocarbons and polyaromatic hydrocarbons, radioactivity, fracturing chemicals and heavy metals for assurance.	Quant	MM	Possible - high	1	-	1	1	1
Post Closure	N/A	13d	13d iii	148	H	Abandonment survey Undertake sampling of groundwater near the pad	High Ambition	Groundwater Sampling of monitoring boreholes and analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals	Quant	MM	Possible - high	1	-	1	1	1
Post Closure	N/A	13d	13d iv	149	-	Abandonment survey Obtain data on drinking water abstraction points (wells, boreholes, springs, surface water abstraction points	0	Drinking water abstraction points Obtain water quality data and water gas content from water abstraction points in the operational area (e.g. regarding dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals)	Quant	MM	Possible - high	1	-	1	1	1
Post Closure	N/A	13d	13d v	150	-	Abandonment survey Undertake land condition (soil) survey around pad	0	Land condition (soil) Establish land condition in immediate are of the pad and analyse for analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, asbestos, chloride	Quant	MM	Possible - high	1	-	1	1	1
Post Closure	N/A	13d	13d vi	151	-	Abandonment survey Undertake survey of biodiversity, ecology and invasive species survey	Assumed to be Middle Ambition	Scope will vary depending on presence of protected species and notable habitats and whether a designated site.	Quant	LL	No	1	-	1	-	1
Post Closure	N/A	13d	13d vii	152	-	Abandonment survey Undertake sampling for methane near surface in the pad location	0	0	Quant	MM	No	1	-	1	1	1
Post Closure	N/A	13d	13d viii	153	L	Abandonment survey Undertake assessment of landuse, infrastructure and buildings	LOW Undertake assessment of landuse, infrastructure and buildings through desk study	LOW AMBITION. Desk study and mapping of landuse, infrastructure and buildings. Objective is to enable comparison with baseline assessment and consequently any impacts.	Quant	LL	No	-	-	-	-	-
Post Closure	N/A	13d	13d viii	154	H	Abandonment survey Undertake assessment of landuse, infrastructure and buildings	HIGH Undertake assessment of landuse, infrastructure and buildings survey through desk study and aerial survey	HIGH AMBITION. As above plus remote (aerial) survey of land, land uses, structures etc. Objective is to enable comparison with baseline assessment and consequently any impacts.	Quant	MM	No	1	-	1	-	1
Post Closure	N/A	13d	13d ix	155	L	Abandonment survey Undertake assessment of ex-anti underground wells and structures	LOW Undertake assessment of underground wells and structures through desk study	LOW AMBITION. Check baseline list of penetrations into zone within area (from well history databases). Relates to wells and structures in place prior to UG activities.	Quant	LL	Possible - high	-	-	-	1	1
Post Closure	N/A	13d	13d ix	156	H	Abandonment survey Undertake assessment of ex-anti underground wells and structures	HIGH Undertake assessment of underground wells and structures desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells	HIGH AMBITION. As per LOW above plus: desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells. Relates to wells and structures in place prior to UG activities.	Quant	MM	No	-	-	-	-	-
Post Closure	N/A	12	12	157	-	Specific post closure risk assessment, well plugging, inspection and monitoring requirements (e.g. for releases to air, well integrity, periodicity of inspections, wellhead monitoring every 90 days)	0	Measure includes: Flush wells with a buffer fluid before plugging Plug wells. Use two cement plugs: one in producing formation and one for surface to bottom of drinking water level, fill the remainder with mud. Perform a mechanical integrity test prior to plugging to evaluate integrity of casing and	Quant	HH	Possible - high	1	1	1	1	1
Post Closure	N/A	13b	13b i	158	-	Specific post closure well inspection, maintenance and monitoring/reporting programme (i) following detection of possible pollution (low ambition); (ii) periodic inspection and monitoring (high ambition)	Post closure well inspection, maintenance and monitoring/reporting programme - following detection of possible pollution (low ambition)	Following detection of possible pollution and after well closure. Well inspection, maintenance and monitoring to ensure integrity. Reports would be prepared and submitted to competent authority by operators. Duration will be until licence surrender. Programme would include: - mechanical integrity testing (MIT) - determination of any necessary maintenance - submission of reports - implementation of remedial actions as necessary	Qual	LH	Possible - high	-	-	-	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Post Closure	N/A	13b	13b ii	159	-	Specific post closure well inspection, maintenance and monitoring/reporting programme (i) following detection of possible pollution (low ambition); (ii) periodic inspection and monitoring (high ambition)	Post closure well inspection, maintenance and monitoring/reporting programme - periodic inspection and monitoring (high ambition)	Well inspection, maintenance and monitoring to ensure integrity on a regular basis (e.g. 3 yearly). Reports would be prepared and submitted to competent authority by operators. Duration will be until licence surrender. Programme would include: - mechanical integrity testing (MIT) - determination of any necessary maintenance - submission of reports - implementation of remedial actions as necessary	Qual	MH	Possible - high	-	-	-	1	1
Post Closure	N/A	13c	13c	160	-	Ownership and liability of wells transferred to a competent authority on surrender of the site licence following a period of monitoring	0	Following a period of monitoring [minimum 20 years] after well/pad closure and subsequent site reinstatement, the site licence is surrendered and the ownership and liability of the wells is transferred to the appropriate competent authority in MSs. Following transfer, the competent authority takes on responsibility and liability for any resultant environmental damage linked to the	Qual	HH	No	-	-	-	1	1
Public Acceptance	N/A	N23	N23	161	-	Public disclosure by operators of environmental monitoring (baseline, operational and post closure), resource use (water use and chemicals), production, incidents (e.g. pollution events, well failure) and well integrity information	0	Operators would be required to publicly disclose baseline, ongoing monitoring and well integrity information through website establishment and maintenance and collation of information. Applies to baseline information through to transfer of responsibility to Competent Authority	Qual	LL	Possible - low	1	-	1	1	1
Public Acceptance	N/A	15	15i	162	L	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) for permitting	LOW AMBITION. Engagement at permitting (website, information, public meetings) and abandonment and relinquishing of permits. (website and information).	Note aspects of public acceptance linked to chemicals are on the chemicals tab. The focus here is on wider public engagement.	Quant	LL	Possible - high	1	1	1	1	1
Public Acceptance	N/A	N41	N41	163	-	Member State Competent Authorities provide information on the licences and permits of operators involved in unconventional gas exploration and production	0	0	Quant	LL	No	-	-	-	1	1
Public Acceptance	N/A	N42	N42	164	-	Prohibit non-disclosure agreements between local residents and/or landowners and unconventional gas operators	0	0	Qual	LL	No	-	-	-	1	1
Public Acceptance	N/A	N40	N40	165	-	Member State Competent Authorities provide a map of planned and existing exploration, production and abandoned well locations	0	Also relevant to underground potentially	Quant	MM	No	1	-	1	-	1
Public Acceptance	N/A	15	15i	166	H	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) for permitting	HIGH AMBITION. As per low ambition PLUS the following: Early stage consultation (initial exploration, pre-site development and pre-permitting) consultation (website, information preparation, public meetings). Production stage ongoing consultation (ongoing website and information provision)	Note aspects of public acceptance linked to chemicals are on the chemicals tab. The focus here is on wider public engagement.	Quant	MM	Possible - low	-	-	-	1	1
Public Acceptance	N/A	N03	N03	167	-	All permits/authorisations/licences relating to environmental risk management to be made available to the public and included on a central data repository for all unconventional gas operations in the Member State / EU	0	0	Qual	MM	No	1	-	1	1	1
Public Acceptance	N/A	N04	N04	168	-	EU institutions and/or Member States provide peer reviewed information to the public on a regular basis on the current state of knowledge of potential environmental risks and benefits from unconventional gas and available measures to manage those risks	0	0	Qual	MM	No	-	-	-	-	-
Other Measures	sea	N34	N34	169	-	Public authorities produce an underground regional impact assessment to optimise resource allocation between unconventional gas and other underground resources (e.g. geothermal energy)	0	0	Quant	LL	No	1	-	1	1	1
Other Measures	permit	N35	N35	170	-	Member States implement integrated permitting for unconventional gas	0	0	Qual	LL	No	-	1	1	1	1
Other Measures	N/A	N25	N25	171	-	Reversal of the burden of proof for unconventional gas operators in the context of liability in case of environmental damage	0	0	Qual	LL	No	-	-	-	-	-
Other Measures	N/A	N38	N38	172	-	Maintain operator liability for any pollution arising from wells for a period of 100 years	0	0	Qual	LM	No	1	-	1	-	1
Other Measures	N/A	N39	N39	173	-	Maintain operator liability for any pollution arising from wells indefinitely	0	0	Qual	LM	No	1	-	1	-	1
Other Measures	operator	N28	N28	174	-	Assessment by the Competent Authority of the technical and financial capacity of an operator	0	0	Qual	LM	No	-	-	-	1	1
Other Measures	trans	59a	59a	175	-	Traffic impact assessment including consideration of noise, emissions and other relevant impacts	0	0	Quant	LM	Possible - high	1	-	1	1	1
Other Measures	operator	N29	N29	176	-	Financial guarantees by operators for environmental and civil liability covering any accidents or unintended negative impacts caused by their own activities or those outsourced to others (to cover incidents and accidents during and after operations, restoration of site)	0	0	Qual	LM	No	-	-	-	1	1
Other Measures	efficiency	N36	N36	177	-	Operators work together to ensure efficient provision of gas collection and wastewater treatment infrastructure	0	0	Qual	LM	No	-	-	-	-	-

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Other Measures	ecology	N21	N21	178	-	Implement precautions to prevent invasive species by cleaning vehicles	0	0	Qual	ML	No	-	-	-	-	-
Other Measures	permit	N15	N15	179	-	Mandatory EIA for all projects expected to involve hydraulic fracturing, before exploration starts	0	0	Quant	ML	No	1	1	1	-	1
Other Measures	permit	N16	N16 i	180	-	Mandatory EIA (i) after initial phase of well exploration and before first test fracturing, and (ii) before production commences	Mandatory EIA according to Directive 2011/92/EU after well exploration and before first test fracturing	0	Quant	ML	No	-	-	-	1	1
Other Measures	permit	N16	N16 ii	181	-	Mandatory EIA (i) after initial phase of well exploration and before first test fracturing, and (ii) before production commences	Mandatory EIA according to Directive 2011/92/EU before production commences	0	Quant	ML	No	-	-	-	1	1
Other Measures	permit	N17	N17	182	-	Assessment of whether full project is likely to have significant effects on the environment during prospecting phase (i.e. extending the existing requirement in relation to deep drillings under the EIA Directive to include screening prior to development of exploration plans/prospecting and taking account of the entire project)	0	0	Quant	ML	No	-	-	-	-	-
Other Measures	incident	N08	N08a	183	-	In the case of an incident/accident significantly affecting the environment: (a) operator informs competent authority immediately; (b) competent authority provides details of the circumstances of the incident and effects on the environment to a designated body at EU level who will make non-confidential information available to the public	In the case of an incident/accident significantly affecting the environment, operator to inform competent authority immediately.	0	Qual	ML	Possible - high	-	-	-	1	1
Other Measures	incident	N08	N08b	184	-	In the case of an incident/accident significantly affecting the environment: (a) operator informs competent authority immediately; (b) competent authority provides details of the circumstances of the incident and effects on the environment to a designated body at EU level who will make non-confidential information available to the public	In the case of an incident/accident significantly affecting the environment, competent authority to provide details of the circumstances of the incident and effects on the environment to a designated body at EU level who will make non-confidential information available to the public	0	Qual	ML	No	-	-	-	-	-
Other Measures	trans	59b	59b	185	-	Transport management plan (including consideration of available road, rail, waterway infrastructure)	0	0	Quant	MM	Possible - high	1	-	1	-	1
Other Measures	trans	60c	60c	186	-	Site selection close to water sources to minimise haulage requirements	0	0	Qual	MM	No	-	-	-	-	-
Other Measures	trans	61b	61b i	187	-	Minimise resources demands and hence traffic movements through (i) water management plans and (ii) wastewater management plans	i) water management plans to minimise water demands and hence traffic movements.	0	Qual	MM	No	1	-	1	1	1
Other Measures	trans	61b	61b ii	188	-	Minimise resources demands and hence traffic movements through (i) water management plans and (ii) wastewater management plans	ii) wastewater management plans to minimise water demands and hence traffic movements.	0	Qual	MM	No	1	-	1	1	1
Other Measures	trans	61c	61c	189	-	Site selection close to wastewater treatment / disposal facilities to minimise haulage requirements	0	0	Qual	MM	No	-	-	-	-	-
Other Measures	incident	N09	N09	190	-	Operator to develop and maintain a contingency plan to address foreseeable impacts of operating conditions on environmental risk management (e.g. degradation of well barriers, casing/cementing as per measure 22)	0	0	Quant	MM	Possible - low	1	-	1	1	1
Other Measures	noi	51a	51a	191	-	Maximum noise levels specified	0	0	Qual	MM	Possible - high	-	-	-	-	-
Other Measures	noi	51c	51c	192	-	Noise screening installation: (i) screen drilling and fracturing rigs with noise barrier / enclosure; (ii) acoustic fencing around the site perimeter.	0	Screen drilling and fracturing rigs with noise barrier/enclosure. Acoustic fencing around the site perimeter	Quant	MM	Possible - high	1	-	1	-	1
Other Measures	noi	51d	51d	193	-	Operational hours specified	0	(Noise abatement)	Qual	MM	Possible - low	1	-	1	-	1
Other Measures	noi	51e	51e	194	-	Vehicle routes specified	0	(Noise abatement)	Qual	MM	Possible - high	1	-	1	-	1
Other Measures	noi	51f	51f	195	-	Machinery orientation and selection to minimise noise	0	(Noise abatement)	Qual	MM	Possible - low	1	-	1	-	1
Other Measures	noi	3a	3a viii	196	-	Site baseline Undertake noise study	0	Consult with relevant regulatory authority and carry out baseline noise monitoring	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	noi	3b	3b viii	197	-	Monitoring Undertake monitoring of noise	0	0	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	monitor	N27	N27	198	-	Member States carry out strategic monitoring of unconventional gas activities at the level of the gas play to assess overall impacts and reaction as necessary	0	0	Quant	MM	No	1	-	1	1	1
Other Measures	guidance	N30	N30	199	-	The European Commission to develop further criteria/guidance for the assessment of environmental impacts from unconventional gas	0	0	Quant	MM	No	-	-	-	-	-
Other Measures	inspection	N31	N31	200	-	Inspections by Competent Authorities during all stages of development (e.g. of well completion reports and environmental risk management and controls)	0	0	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	skills	N32	N32	201	-	Competent Authorities have available sufficient inspection capacity and appropriately skilled inspectors	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	inspection	N33	N33	202	-	Independent inspection during all stages of development of well integrity	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	ecology	N37	N37	203	-	Pad construction activities staged to reduce soil erosion and to coincide with low rainfall periods	0	0	Qual	MM	No	-	-	-	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Other Measures	baseline	3a	3a iv	204	-	Site baseline Obtain data on drinking water abstraction points (wells, boreholes and springs)	0	Develop list of wells, boreholes, springs, surface water abstraction points within area (from public data). List names and depth of all potentially affected (by UG) underground sources of drinking water Provide geochemical information and maps/cross section on subsurface aquifers. Obtain water quality data and water gas content from existing available data.	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	monitor	3a	3a v	205	-	Site baseline Undertake land condition (soil) survey around pad	0	Trial pits and analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, asbestos, chloride.	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	trans	3a	3a vii	206	L	Site baseline Undertake transport and traffic study.	LOW AMBITION Undertake transport and traffic study. Liaise with highway authority and identify relevant routes to/from well pad	0	Quant	MM	Possible - high	1	-	1	-	1
Other Measures	trans	3a	3a vii	207	H	Site baseline Undertake transport and traffic study.	HIGH AMBITION Undertake transport and traffic study. As per LOW plus traffic survey and traffic modelling	0	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	ecology	3a	3a ix	208	-	Site baseline Undertake survey of biodiversity and ecology survey	Assumed to be Middle Ambition	Scope will vary depending on presence of protected species and notable habitats and whether a designated site.	Quant	MM	Possible - low	1	-	1	1	1
Other Measures	baseline	3a	3a xii	209	L	Site baseline Undertake assessment of landuse, infrastructure and buildings	LOW AMBITION. Undertake assessment of landuse, infrastructure and buildings through desk study	Desk study	Quant	MM	Possible - high	1	-	1	-	1
Other Measures	baseline	3a	3a xii	210	H	Site baseline Undertake assessment of landuse, infrastructure and buildings	HIGH AMBITION. As LOW plus remote (aerial) survey of land, land uses, structures etc.	0	Quant	MM	No	1	-	1	-	1
Other Measures	monitor	3b	3b iv	211	-	Monitoring Undertake monitoring of drinking water abstraction points (wells, boreholes, springs, surface water)	0	Obtain water quality data and water gas content from existing available data. Ongoing monitoring. Annual desk study using data from abstraction points	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	monitor	3b	3b v	212	-	Monitoring Undertake land condition (soil) tests every five years outside site boundary	0	Analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, chloride).	Quant	MM	No	1	-	1	-	1
Other Measures	trans	3b	3b vii	213	-	Monitoring Undertake monitoring of traffic numbers and patterns	0	Traffic count site/system to provide weekly or monthly counts.	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	monitor	3b	3b xi	214	-	Monitoring Undertake monitoring of energy source and use	0	0	Quant	MM	No	1	-	1	-	1
Other Measures	monitor	3b	3b xii	215	-	Monitoring Undertake monitoring of greenhouse gas emissions	0	0	Quant	MM	No	-	-	-	1	1
Other Measures	ecology	3b	3b xvi	216	-	Monitoring Undertake periodic surveys of biodiversity, ecology and invasive species	Assumed to be Middle Ambition	Scope and frequency will vary depending on presence of protected species and notable habitats and whether a designated site. Invasive species mitigation plan if required	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	incident	3b	3b xix	217	-	Monitoring Undertake monitoring of spills volume, nature, location and clean-up (including reporting)	0	0	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	cumulative	7	7	218	-	Cumulative effects (e.g. air pollution, traffic impacts, water resource requirements) of gas play development assessed in planning and permitting taking into account other (non-unconventional gas) developments and plans	0	Complimentary with other measures associated with planning. Linked to SEA	Qual	MM	No	-	-	-	1	1
Other Measures	permit	N02	N02	219	-	Operator, as part of permit conditions, obtains independent evaluation of environmental risk management measures for gas concession before fracturing commences and at regular intervals thereafter	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	permit	N06	N06	220	-	Operations to be subject to an integrated permit from the national authority, setting measures to manage environmental impacts for all environmental media (air surface/ground water, land). Combined monitoring and inspection regimes where separate competent authorities exist	0	0	Quant	MM	No	1	1	1	1	1
Other Measures	sea	N13	N13	221	-	Member States carry out SEA to set up plans/programmes setting the framework for unconventional gas projects before granting concessions for unconventional gas exploration and production and assess environmental effects of such plans. Assessment to address surface aspects such as water abstraction, waste treatment and disposal, transport, air quality, landtake, species diversity as well as known underground risks. Assessment to be reviewed before production commences on the basis of information obtained during the exploration phase. Those MS that have already granted concessions to perform	0	0	Quant	MM	No	-	-	-	1	1
Other Measures	equip	N18	N18	222	-	Ensure equipment is compatible with composition of fracturing chemicals	0	0	Qual	MM	Possible - high	1	-	1	-	1
Other Measures	equip	N19	N19	223	-	Carry out thorough planning and testing of equipment prior to hydraulic fracturing operations	0	0	Qual	MM	Possible - high	1	-	1	-	1
Other Measures	management	N20	N20	224	-	Environmental management system accreditation for unconventional gas installation operators	0	0	Quant	MM	No	1	-	1	-	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	**Sub**	**Measure ref.**		**Order**	**LOW vs. HIGH**	**Measure**	**Sub-measure description**	**Further definition**	**Quant/ qual**	**LoA rating**		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Other Measures	materi als	30e	30e	225	-	Muds restricted to approved list with known properties/safety data or non-toxic drilling muds	Restrict muds to approved list	Specify the use of muds from an approved list to minimise the risk of harmful (polluting) mud production which could result in polluting spills	Qual	MH	No	-	-	-	-	-
Other Measures	materi als	30e	30e	226	-	Muds restricted to approved list with known properties/safety data or non-toxic drilling muds	Restrict muds to non-toxic drilling muds	Specify the use of water-based muds/non-toxic chemical additives	Qual	HH	No	1	1	1	-	1
Other Measures	manag ement	29e	29e	227	-	Site reinstatement plan	0	Purpose of measure is to develop a reinstatement plan for the site following well closure and abandonment.	Quant	MH	Yes	1	-	1	1	1
Other Measures	inciden t	9b	9b	228	-	Emergency response plan developed and put in place covering: - leaks from the well to groundwater or surface water - releases of flammable gases from the well or pipelines - fires and floods - leaks and spillage of chemicals, flowback or produced water - releases during transportation	0	0	Qual	HM	Yes	-	1	1	1	1
Other Measures	inciden t	9a	9a	229	-	Consideration of major hazards for all stages in the life cycle of the development (early design, through operations to post abandonment) and development of HSE case or similar demonstrating adequacy of the design, operations and HSE management (including emergency response) for both safety and environmental major impacts	0	0	Qual	HH	Possible - high	1	1	1	1	1
Other Measures	trans	60a	60a	230	-	Use of temporary surface pipes for distribution of water supply	0	Temporary pipes laid above ground to supply water to pads.	Qual	HH	No	-	-	-	-	-
Other Measures	trans	60b	60b	231	-	Use of temporary surface pipes for collection of flowback	0	Temporary pipes laid above ground to collect flowback and transport to treatment plant.	Qual	HH	No	-	-	-	-	-
Other Measures	trans	61a	61a	232	-	Use of temporary surface pipes for collection of produced water	0	Temporary pipes laid above ground to collect produced water and transport to treatment plant.	Qual	HH	No	-	-	-	-	-

Non-BAU Measures in Policy Options

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Zoning	N/A	42b	42b	1	-	Location of sites close to existing pipeline infrastructure	0	Site selection takes into consideration existing gas pipeline infrastructure to enable minimisation of the need for additional pipeline infrastructure and associated development impacts	Qual	LL	No	1	-	1	-	1
Zoning	N/A	N48	N48	2	-	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers and the surface to be determined based on risk assessment	0	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	26c	26c	3	-	Fracturing to be a minimum distance from water resources	0	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	40c	40c	4	-	High land, agricultural and ecological value locations avoided	0	Assessment of and avoidance of high land, agricultural and ecological value locations (e.g. Natura 2000 sites, conservation sites).	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	5	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Buffer zone from abstraction points and aquifers of 1,000m for drinking water related abstraction	Applicable regardless of area type (i.e. not limited to Natura 2000 site and other specified sites). Hence applicability is broader.	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	6	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Buffer zone from residential areas, schools hospitals and other sensitive areas of 1,600m	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	7	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Buffer zone within which detailed noise assessment is required of 305m	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	8	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Buffer zone from abandoned wells and other potential pathways for fluid migration (distance specified on risk basis)	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	9	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Additional containment for sites near surface water supply locations	This is required for sites within 800m of water supply locations in Colorado. The definition of additional containment is not provided - assume bunded tanks/site - see other measures re. this in surface water	Qual	MM	No	1	-	1	-	1
Zoning	N/A	40a	40a	10	-	Optimisation from an environmental perspective, i.e. the number of wells, pad density and pad spacing	0	Optimise the number of wells per pad, pad density and pad spacing to minimise cumulative environmental impacts (e.g. one pad per 2.6 km2 proposed by New York State). This will include consideration of siting with consideration of conflicts with nearby or adjacent sensitive land uses such as residences, schools, hospitals, available transport infrastructure, access to water supply, access to wastewater treatment, etc. Note: the acquis communautaire requires this measure, but it is uncertain whether it is	Qual	HM	No	1	-	1	-	1
Zoning	N/A	40b	40b	11	-	Compatibility with current and future potential landuse (Natura 2000 sites, conservation sites, human use, industrial use, appropriate zoning, CCS, geothermal, water abstraction)	0	Assessment of compatibility with current and future landuse plans (e.g. Natura 2000 sites, conservation sites, human use, industrial use, appropriate zoning. Note: the acquis communautaire requires this measure, notably as a mitigation measure under the SEAD/the EIAD, but without guarantee of the result, Natura2000 Directives	Qual	HM	No	1	-	1	-	1
Zoning	N/A	1b	1b	12	-	Restrict operations within and underneath specified sites (e.g. Natura 2000, protected sites, coal mining areas, drinking water protection areas, water extraction areas for public drinking water supply, mineral spa protection zones karstic aquifers, flood prone zones and mineral water reserves, reforestation areas and areas known to be unfavourable - with regard to potential environmental impacts) or within certain distances to specified sites	0	Operations would be restricted (i.e. greater controls as required by discretion of MS authorities) within specified areas. Areas known to be unfavourable - with regard to potential environmental impacts - geological and hydrogeological conditions (groundwater potentials and pathways, tectonically fractured rocks, artesian confined aquifers, suspected pathways introduced by abandoned boreholes	Qual	HM	Yes	1	-	1	-	1
Zoning	N/A	55e	55e	13	-	Avoid high seismicity risk areas	0	0	Qual	HH	No	1	-	1	-	1
Zoning	N/A	55i	55i	14	-	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers (e.g. 600m) and the surface (e.g. 600m depth requires special permit)	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers of, e.g. 600m	0	Qual	HH	No	1	-	1	-	1
Zoning	N/A	55i	55i	15	-	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers (e.g. 600m) and the surface (e.g. 600m depth requires special permit)	Special permit conditions where hydraulic fracture pipes are less than, e.g. 600m depth from surface	0	Qual	HH	No	1	-	1	-	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	**Sub**	**Measure ref.**		**Order**	**LOW vs. HIGH**	**Measure**	**Sub-measure description**	**Further definition**	**Quant/ qual**	**LoA rating**		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Zoning	N/A	1a	1a	16	-	Prohibit operations within and underneath specified sites (e.g. Natura 2000, protected sites, coal mining areas, drinking water protection areas, water extraction areas for public drinking water supply, mineral spa protection zones karstic aquifers, flood prone zones and mineral water reserves, reforestation areas and areas known to be unfavourable - with regard to potential environmental impacts) or within certain distances to specified sites	0	Areas known to be unfavourable - with regard to potential environmental impacts - geological and hydrogeological conditions (groundwater potentials and pathways, tectonically fractured rocks, artesian confined aquifers, suspected pathways introduced by abandoned boreholes or mining activities)	Qual	HH	Yes	1	-	1	-	1
Underground Risks	N/A	N44	N44	17	-	Competent authorities compile regional maps of underground resources	0	0	Qual	LL	No	1	-	1	-	1
Underground Risks	N/A	N55	N55	18	-	Conduct 2D seismic survey to identify faults and fractures.	0	0	Quant	LM	Yes	1	1	1	1	1
Underground Risks	N/A	28d	28d	19	-	Sharing of information to ensure that all operators in a gas play are aware of risks and can therefore plan	0	0	Qual	LM	Possible - low	1	1	1	1	1
Underground Risks	N/A	N45	N45	20	-	Members States establish a capability to address groundwater contamination arising from unconventional gas operations. In the case of transboundary aquifers, joint capability established	0	0	Qual	LM	No	1	-	1	-	1
Underground Risks	N/A	55g	55g	21	-	Engagement with third parties (e.g. regulators, other operators, researchers) to ensure fully aware of any issues / proximity (e.g. to other underground activities)	0	0	Qual	ML	Possible - low	1	-	1	-	1
Underground Risks	N/A	22d	22d	22	-	Search for and document potential leakage pathways (e.g. other wells, faults, mines)	0	Through delivery of 3 a x detail	Quant	MM	Possible - high	1	1	1	1	1
Underground Risks	N/A	26d	26d i	23	L	i) Development of a conceptual model of the zone before work commences covering geology, groundwater flows, pathways, microseismicity and subsequent updating of the model as information becomes available ii) as above plus Modelling of the impact of groundwater pumping on linked groundwater and surface water flows and quality	Related to 3a x-a4 (which is Low Ambition)	Through delivery of 3 a x detail	Quant	MM	No	1	1	1	1	1
Underground Risks	N/A	26e	26e	25	-	Modelling of fracturing programme to predict extent of fracture growth based on best information	0	Application of Discrete Fracture Network (DFN) approach including dynamic response (e.g. hydro-shearing), Finite Element Analysis (FEA) or Discrete Element Method (DEM). 3D fracture modelling integrated with geomechanics modelling	Quant	MM	No	1	-	1	1	1
Underground Risks	N/A	26g	26g	26	-	Implementation of remedial measures if well failure occurs	0	0	Qual	MM	Yes	1	1	1	1	1
Underground Risks	N/A	55c	55c	27	-	Ground motion prediction models to assess the potential impact of induced earthquakes	0	0	Quant	MM	No	-	-	-	-	-
Underground Risks	N/A	N09	N09	28	-	Operator to develop and maintain a contingency plan to address foreseeable impacts of operating conditions on environmental risk management (e.g. degradation of well barriers, casing/cementing as per measure 22)	0	0	Quant	MM	No	-	-	-	1	1
Underground Risks	N/A	N05	N05	29	-	Initiate immediate flowback post fracturing	0	0	Qual	MM	No	1	1	1	-	1
Underground Risks	N/A	N46	N46	30	-	The European Commission develops criteria/guidance for underground risk assessment (such as criteria to assess potential risks of groundwater contamination and induced seismicity) related to unconventional gas	0	0	Qual	MH	No	-	-	-	-	-
Underground Risks	N/A	N07	N07	31	-	Operator to use alternative fracturing fluids to water (e.g. nitrogen, CO2, propane)	0	0	Qual	MH	No	-	-	-	-	-
Underground Risks	N/A	55h	55h	32	-	Smaller preinjection prior to main operations to enable induced seismicity response to be assessed	0	Mini-fractures area carried out prior to full scale fracturing. Monitoring of the seismic response to the mini-fractures is carried out and assessment of the location's actual response compared with the modelled response is made. Analysis of results and conclusion drawn regarding suitability of and approach to full scale operations. Enables model predictions to be verified and the actual response of geological formations to be assessed.	Qual	MH	No	1	-	1	-	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Underground Risks	N/A	22a	22a	33	-	Key elements to maintain well safety such as: • blowout preventers • pressure & temperature monitoring and shutdown systems • fire and gas detection • continuous monitoring for leaks and release of gas and liquids • modelling to aid well/HF design • isolate underground source of drinking water prior to drilling • ensure micro-annulus is not formed • casing centralizers to centre casing in hole • select corrosive resistant alloys and high strength steel • fish back casing • maintain appropriate bending radius • triple casing • casing and cementing designed to sustain high pressure and low magnitude seismicity • isolation of the well from aquifers • casings: minimum distance the surface casing extends below aquifer (e.g. 30m below the deepest underground source of drinking water encountered while drilling the well, ref. Environment Agency 2012) and surface casing cemented before reaching depth of e.g. 75m below underground drinking water (ref. AEA 2012). Production casing cemented up to at least 150 metres above the formation where hydraulic	0	Measures to be split out for cost purposes	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b i	34	-	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	i) wireline logging (calliper, cement bond, variable density)	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b ii	35	-	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b iii	36	-	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	iii) mechanical integrity testing of equipment (MIT)	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b iv	37	-	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	iv) casing inspection test and log	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22c	22c	38	-	Multiple barriers between the target formation and people/the environment, including minimum vertical distance between target formation and aquifers	0	0	Qual	HH	No	1	1	1	-	1
Underground Risks	N/A	26f	26f	39	-	Monitoring and control during operations to ensure hydraulic fractures / pollutants do not extend beyond the gas-producing formations and does not result in seismic events or damage to buildings/installations that could be the result of fracturing	0	Linked to 3 b xvii	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3a	3a xi	40	-	Site baseline Establish the presence of methane in groundwater, including drinking water	0	0	Quant	MM	Yes	1	1	1	1	1
Underground Risks	N/A	55d	55d	41	L	Microseismicity monitoring and management requirements during operations	LOW AMBITION Real time monitoring of microseismicity during all operations	Linked to 3 b xvii	Quant	MM	No	-	1	1	1	1
Underground Risks	N/A	55d	55d	42	-	Microseismicity monitoring and management requirements during operations	HIGH AMBITION AS LOW plus cessation of fracturing if specified induced seismic activity is detected (using traffic light system)	0	Qual	HH	No	1	1	1	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Underground Risks	N/A	3a	3a iii	43	L	Site baseline Undertake sampling of groundwater	MEDIUM AMBITION Sampling of shallow groundwater during wet and dry periods (cost is shown in Middle Ambition column)	Concentrate boreholes near pad (as on impacts on groundwater due to surface spills greatest near pad). Boreholes, at 15m depth at each corner. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals.	Quant	MM	Yes	-	-	-	-	-
Underground Risks	N/A	3a	3a iii	44	H	Site baseline Undertake sampling of groundwater	HIGH AMIBITION Borehole to sample deep groundwater and characterise the hydrological series (cost is shown in High Ambition column)	Deep boreholes in area. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals.	Quant	HH	Possible - low	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a1	45	-	Site baseline Geological, hydrogeological and seismic conceptual model [1] Obtain and analyze seismic (earthquake) history.	0	0	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a2	46	L	Site baseline Geological, hydrogeological and seismic conceptual model [2] Obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures	LOW AMBITION. Undertake desk study based on existing data and literature	0	Quant	MH	Yes	-	-	-	-	-
Underground Risks	N/A	3a	3a x-a2	47	H	Site baseline Geological, hydrogeological and seismic conceptual model [2] Obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures	HIGH AMBITION. In addition LOW obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures through new cores and stratigraphic tests	0	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a3	48	-	Site baseline Geological, hydrogeological and seismic conceptual model [3] Undertake surface microseismic survey	0	0	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a4	49	L	Site baseline Geological, hydrogeological and seismic conceptual model [4] Undertake complex modelling of fluid flows and migration (reservoir simulations)	LOW AMBITION. Modelling over 100 years	0	Quant	MH	No	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a4	50	H	Site baseline Geological, hydrogeological and seismic conceptual model [4] Undertake complex modelling of fluid flows and migration (reservoir simulations)	HIGH AMBITION. Modelling is done over 10,000 years	0	Quant	HH	No	-	-	-	-	-
Underground Risks	N/A	3a	3a x-a5	51	-	Site baseline Geological, hydrogeological and seismic conceptual model [5] Develop maps and cross sections of local geologic structure	0	0	Quant	HH	Possible - low	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a6	52	H	Site baseline Geological, hydrogeological and seismic conceptual model [6] Conduct 3D seismic survey to identify faults and fractures	0	0	Quant	HH	Possible - low	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a7	53	-	Site baseline Geological, hydrogeological and seismic conceptual model [7] Obtain data on area, thickness, capacity, porosity and permeability of formations	0	0	Quant	HH	Possible - high	1	1	1	1	1
Underground Risks	N/A	3a	3a xiii	54	L	Site baseline Undertake assessment of existing underground wells and structures	LOW AMBITION. Undertake assessment of underground wells and structures	Develop list of penetrations into zone within area (from well history databases).	Quant	MH	Possible - high	-	-	-	-	-
Underground Risks	N/A	3a	3a xiii	55	H	Site baseline Undertake assessment of existing underground wells and structures	HIGH AMBITION. As LOW AMBITION plus undertake assessment of underground wells and structures desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells	0	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3b	3b iii	56	L	Monitoring Undertake monitoring of groundwater	MEDIUM AMBITION Sampling of shallow groundwater during wet and dry periods	Concentrate boreholes near pad (as on impacts on groundwater due to surface spills greatest near pad). Boreholes, at 15m depth at each corner. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals.	Quant	MM	Yes	-	-	-	-	-
Underground Risks	N/A	3b	3b iii	57	H	Monitoring Undertake monitoring of groundwater	HIGH AMBITION Deep groundwater sampling network to determine the characteristics of deep groundwater and formation water and piezometric levels	Deep boreholes network in area. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals.	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3b	3b xvii	58	-	Monitoring Undertake monitoring of induced seismicity from fracturing	0	0	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3b	3b xviii	59	-	Monitoring Undertake monitoring for presence of methane seepages in groundwater, including drinking water.	0	0	Quant	HH	Possible - low	-	-	-	-	-

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	**Sub**	**Measure ref.**		**Order**	**LOW vs. HIGH**	**Measure**	**Sub-measure description**	**Further definition**	**Quant/ qual**	**LoA rating**		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Chemical Use	N/A	CSL5	CSL5	60	-	Authorities to organise an exchange of views/information on environmentally safer technologies and alternatives to the use of chemicals in hydraulic fracturing	0	0	Qual	LL	No	1	-	1	-	1
Chemical Use	N/A	N24	N24	61	-	Traceability of chemicals used by an operator	0	0	Qual	LL	No	-	-	-	-	-
Chemical Use	N/A	CAL1	CAL1	62	-	CSA/risk assessment explicitly specific to hydraulic fracturing in the EU to be included in REACH Registration	Chemicals - assessment	Cost to be estimated based on existing data in #11.	Quant	ML	No	-	-	-	-	-
Chemical Use	N/A	CAL2	CAL2	63	-	Develop a peer-reviewed EU-level exposure scenario / SpERC for HF for different chemical types	Chemicals - assessment	Estimated cost of developing SpERC to similar level of detail to those that already exist for e.g. additives used in petroleum products (CONCAWE/ESIG) http://www.cefic.org/Industry-support/Implementing-reach/Guidances-and-Tools1/	Quant	ML	No	1	-	1	-	1
Chemical Use	N/A	CAL3	CAL3	64	-	CAL2 to be implemented in CSAs for chemicals used in HF and any deviations explained	Chemicals - assessment	Should be feasible to estimate additional cost of UG company doing their own CSA for this specific use for typical number of chemicals used	Quant	ML	No	1	-	1	-	1
Chemical Use	N/A	CDL1	CDL1	65	-	Disclosure of information to Competent Authority: declaration of substance name and CAS number for the chemical substances potentially to be used in hydraulic fracturing. Per concession/play	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity)	Qual	ML	No	1	-	1	1	1
Chemical Use	N/A	CDL2	CDL2	66	-	Disclosure of information to the public: list of chemicals potentially to be used in hydraulic fracturing by UG company to be made available (e.g. via company website or centralised data dissemination portal). Per concession/play	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity)	Qual	ML	Possible - high	1	-	1	1	1
Chemical Use	N/A	CSL1a	CSL1a	67	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A or 1B	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL1b	CSL1b	68	-	Non-use in biocidal products of any substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A or 1B	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL1c	CSL1c	69	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as aquatic acute category 1 or aquatic chronic category 1	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL1d	CSL1d	70	-	Non-use in biocidal products of any substances with [harmonised or notified] classification as aquatic acute category 1 or aquatic chronic category 1	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL2	CSL2	71	-	Non-use of any substances on REACH Candidate List for authorisation (substances of very high concern)	Chemicals - selection	Too many substances potentially used in HF to robustly estimate differences in costs. Impacts on well productivity will far outweigh differences in prices of fluid additives	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL3	CSL3	72	-	Negative list of named substances that must not be used in UG extraction (alternative to two measures CSL1 and CSL2)	Chemicals - selection	Partially quantitative. Potential to cost actually developing the list but costs of not using substances on that list not quantifiable as per measures above	Quant	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL4	CSL4	73	-	Demonstration that all steps practicable have been taken to reduce number, concentration and volume of chemicals used in hydraulic fracturing	Chemicals - selection	Not considered feasible to quantify costs as too site-specific.	Qual	ML	No	1	1	1	1	1
Chemical Use	N/A	CSM4	CSM4	74	-	Establish general principles for the use of chemicals (minimise use, substitution by less hazardous substances), oblige operator to present and discuss alternative substances and establish third party verification.	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CAM1	CAM1	75	-	Chemical safety assessment / biocide risk assessment includes assessment of risks of potential transformation products in HF / underground context, as part of permit/licence, with risk management measures implemented accordingly	Chemicals - assessment	Could be e.g. 2-3 times cost for standard CSA / risk assessment?	Quant	MM	No	-	-	-	-	-
Chemical Use	N/A	CSM2	CSM2	76	-	Positive list of substances expected to be safe under EU UG extraction conditions and require operators to only use substances on this positive list	Chemicals - selection	Partially quantitative. Potential to cost actually developing the list but costs of only using substances on that list not quantifiable as per measures above	Quant	MM	No	1	1	1	1	1
Chemical Use	N/A	CSM3	CSM3	77	-	Selection of substances (chemicals and proppants) that minimise the need for treatment when present in flowback water	Chemicals - selection	Not considered feasible to quantify costs as insufficient data on which substances (from a very large list) require more/less treatment under different circumstances	Qual	MM	No	1	1	1	1	1
Chemical Use	N/A	3b	3b x	78	-	Monitoring Undertake monitoring of chemicals type and volume used including record keeping	0	0	Quant	MM	Possible - low	1	-	1	1	1
Chemical Use	N/A	CSM1a	CSM1a	79	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A, 1B or 2	Chemicals - selection	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A, 1B or 2	Qual	LH	No	1	1	1	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Chemical Use	N/A	CSM1 b	CSM1b	80	-	Non-use in biocidal products of any substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A, 1B or 2	Chemicals - selection	Non-use in biocidal products of any substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A, 1B or 2	Qual	LH	No	1	1	1	1	1
Chemical Use	N/A	CSM1 c	CSM1c	81	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as aquatic acute category 1 or 2 or aquatic chronic category 1 or 2	Chemicals - selection	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as aquatic acute category 1 or 2 or aquatic chronic category 1 or 2	Qual	LH	No	1	1	1	1	1
Chemical Use	N/A	CSM1 d	CSM1d	82	-	Non-use in biocidal products of any substances with [harmonised or notified] classification as aquatic acute category 1 or 2 or aquatic chronic category 1 or 2	Chemicals - selection	Non-use in biocidal products of any substances with [harmonised or notified] classification as aquatic acute category 1 or 2 or aquatic chronic category 1 or 2	Qual	LH	No	1	1	1	1	1
Chemical Use	N/A	CDM1	CDM1	83	-	Disclosure of information to Competent Authority: declaration of substance name, CAS number, precise concentrations, quantities and all physicochemical and (eco)toxicological data for the substances potentially to be used in hydraulic fracturing. Also potentially e.g. date of fracturing, total volume of fluids, type and amount of proppant; description of the precise additive purpose; concentration in the total volume. Per well. Prior to and after operations	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity)	Qual	HL	Possible - high	1	-	1	1	1
Chemical Use	N/A	CDM2	CDM2	84	-	Disclosure of information to public: list of chemicals and CAS numbers used to be made available (e.g. via company website and centralised data dissemination portal) for the chemicals potentially to be used in hydraulic fracturing. Per concession/play. Prior to and after operations	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity)	Qual	HL	No	1	-	1	1	1
Chemical Use	N/A	N26	N26	85	-	Select proppants which minimise the HVHF treatment required	0	0	Qual	MH	No	1	1	1	1	1
Chemical Use	N/A	CAH1	CAH1	86	-	Chemical safety assessment / biocide risk assessment includes assessment of risks of mixtures of chemicals used in HF as part of permit/licence, with risk management measures implemented accordingly. To include potential additive or synergistic impacts	Chemicals - assessment	Scientifically challenging and not likely to be possible to quantify with any degree of certainty.	Qual	HM	No	-	-	-	-	-
Chemical Use	N/A	CDH1	CDH1	87	-	Disclosure of information to public: details of substance name, CAS number, concentrations, and all physicochemical and (eco)toxicological data for the substances potentially to be used in hydraulic fracturing. This is to be made available (e.g. via company website and centralised data dissemination portal). Also potentially e.g. date of fracturing, total volume of fluids, type and amount of proppant; description of the overall purpose of the additives; concentration in the total volume. Per well. Prior to and after operations	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity).	Qual	HM	Possible - low	1	-	1	1	1
Chemical Use	N/A	CSH2 a	CSH2a	88	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification for any health or environmental effects	Chemicals - selection	0	Qual	MH	No	1	1	1	1	1
Chemical Use	N/A	CSH2 b	CSH2b	89	-	Non-use in biocidal products of any substances with [harmonised or notified] classification for any health or environmental effects	Chemicals - selection	0	Qual	MH	No	1	1	1	1	1
Chemical Use	N/A	CSH1	CSH1	90	-	Use of water or inert materials only in hydraulic fracturing	Chemicals - selection	Not thought to be practicable and likely to have significant impact on viability and productivity of UG extraction. Not considered practical to quantify costs - main impact will be on well productivity, maintenance frequency, etc.	Qual	HH	No	1	1	1	1	1
Water Depletion	N/A	38a	38a i	91	-	i) Notification of water demand from fracturing operations to relevant water utilities and competent authorities	0	Inform relevant authorities (i.e. water utilities, environmental regulators, planning authorities) of water demand for the lifetime of the project.	Qual	LM	No	1	1	1	1	1
Water Depletion	N/A	38b	38b	93	-	Demand profile for water	0	Establish the water demand pattern taking account of number of wells, pad locations, drilling sequence, water consumption per unit operation. Establish flow patterns including peak and average flow volumes under a variety of scenarios	Quant	LM	Possible - high	1	-	1	1	1
Water Depletion	N/A	N49	N49	94	-	Strategic planning and staged approach of play development to avoid peaks in water demand	0	0	Qual	MM	No	1	-	1	-	1
Water Depletion	N/A	38c	38c	95	-	Water management plan	0	Develop a water management plan to cover water supply and efficient use on site.	Qual	MM	Possible - high	1	1	1	1	1
Water Depletion	N/A	3a	3a vi	96	-	Site baseline Establish water source availability and test for suitability	0	Locate water sources and identifying availability, water rights. Test water sources for suitability	Quant	MM	Possible - high	1	-	1	1	1
Water Depletion	N/A	3b	3b vi	97	-	Monitoring Water resources availability	0	0	Quant	MM	No	1	-	1	1	1
Water Depletion	N/A	3b	3b ix	98	-	Monitoring Undertake monitoring of water volumes and origin	0	0	Quant	MM	No	1	-	1	1	1
Water Depletion	N/A	38d	38d	99	-	Reuse of flowback and produced water for fracturing	0	Reuse flowback and/or produced water to make up fracture fluid.	Quant	MM	No	1	-	1	1	1
Water Depletion	N/A	38e	38e	100	-	Use of lower quality water for fracturing (e.g. non-potable ground / surface water, rainwater harvesting, saline aquifers, sea water, treated industrial waterwaters)	0	Use lower quality water (non-potable) to make up fracture fluid.	Qual	MM	No	1	1	1	-	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Surface Water	N/A	33i	33i	101	-	Good site security	0	Operators would be required to ensure that the site is protected properly to prevent vandalism that may lead to pollution from damaged equipment/infrastructure	Quant	ML	Yes	-	-	-	-	-
Surface Water	N/A	29a	29a	102	-	Good practice construction / deconstruction practices, including design for well abandonment	0	Note - also included in post closure ref. demolition. Operators should apply construction industry good practice to prevent pollution of surface water through operator training and approach to construction practice	Qual	MM	Possible - high	1	1	1	1	1
Surface Water	N/A	33a	33a	103	-	Good site practice to prevention of leaks and spills	0	0	Qual	MM	Yes	1	1	1	1	1
Surface Water	N/A	33d	33d	104	-	Spill kits available for use	0	0	Quant	MM	Yes	1	1	1	1	1
Surface Water	N/A	3a	3a ii	105	H	Site baseline Undertake sampling of surface water bodies in wet and dry periods	High Ambition	Analyse for suspended solids, BOD, dissolved oxygen, pH, ammonia, chloride also total petroleum hydrocarbons and polyaromatic hydrocarbons, radioactivity, fracturing chemicals and heavy metals for assurance.	Quant	MM	Possible - low	1	1	1	1	1
Surface Water	N/A	3b	3b ii	106	L	Monitoring Undertake monitoring of surface water bodies in wet and dry periods	LOW AMBITION Monitoring Undertake monitoring of surface water bodies in wet and dry periods	Analyse for suspended solids, BOD, dissolved oxygen, pH, ammonia, chloride also total petroleum hydrocarbons and polyaromatic hydrocarbons, radioactivity, fracturing chemicals and heavy metals for assurance.	Quant	MM	Possible - high	-	1	1	1	1
Surface Water	N/A	3b	3b ii	107	H	Monitoring Undertake monitoring of surface water bodies in wet and dry periods	HIGH AMBITION AS LOW AMBITION with alert system promoting corrective action	0	Quant	MH	No	1	-	1	-	1
Surface Water	N/A	33e	33e	108	-	Berm around site boundary	0	0	Quant	HM	No	1	1	1	-	1
Surface Water	N/A	33g	33g	109	-	Collection and control of surface runoff	0	Operators construct sites to effectively collect and control stormwater, e.g. draining to a single collection point, to enable effective control and management of any spills and leaks.	Quant	MH	Possible - high	1	-	1	1	1
Surface Water	N/A	29c	29c	110	-	Bunding of fuel tanks	0	0	Quant	HH	No	1	-	1	-	1
Surface Water	N/A	30d	30d	111	-	Use of closed tanks for mud storage	0	0	Quant	HH	Possible - low	-	-	-	-	-
Surface Water	N/A	33b	33b	112	-	Use of tank level alarms	0	For chemicals, fracturing fluid, muds and wastewaters. Activation triggers corrective action/contingency plan implementation.	Quant	HH	Possible - high	1	1	1	1	1
Surface Water	N/A	33c	33c	113	H	Use of double skinned closed storage tanks	High Ambition	For chemicals, fracturing fluid, muds and wastewaters	Quant	HH	No	1	1	1	1	1
Surface Water	N/A	33f	33f	114	-	Impervious site liner under pad with puncture proof underlay	0	0	Quant	HH	Yes	1	-	1	1	1
Air Quality	N/A	59d	59d	115	-	Use of vehicles (water, chemicals, waste trucking) that meet minimum air emission standards e.g. EURO standards	0	0	Qual	LL	No	-	-	-	-	-
Air Quality	N/A	N54	N54	116	-	Encourage industry voluntary approach to reduce air pollutants and greenhouse gases	0	0	Qual	LM	No	1	-	1	-	1
Air Quality	N/A	16b	16b i	117	-	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	Low emission power supply (switching to LPG)	0	Quant	LM	No	1	-	1	-	1
Air Quality	N/A	16b	16b ii	118	-	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	Low emission power supply (switching to grid electricity)	0	Quant	LM	No	1	-	1	-	1
Air Quality	N/A	16d	16d	119	-	Application of abatement techniques to minimise emissions (assumed SCR for NOx and Diesel Particulate Filter (DPF) for PM).	0	SCR for NOx Diesel Particulate Filter (DPF) for PM	Quant	LM	No	1	-	1	-	1
Air Quality	N/A	17c	17c	120	L	Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network)	LOW AMBITION Flares or incinerators to reduce emissions from fracturing fluid at exploration stage	Capture gas from fracture fluid at exploration stage and flare or incinerate	Quant	MM	Yes	-	-	-	-	-
Air Quality	N/A	17c	17c	121	H	Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network)	HIGH AMBITION As LOW AMBITION with no audible or visible flaring	0	Quant	MM	No	-	-	-	-	-
Air Quality	N/A	3a	3a i	122	-	Site baseline Undertake sampling of air quality	0	Three month monitoring period to establish baseline using passive monitoring techniques at circa six points in the vicinity of a pad. Monitoring for combustion gasses (NOx, NO2, PM10 and also SO2, CO and VOCs).	Quant	MM	Possible - high	1	1	1	1	1
Air Quality	N/A	3b	3b i	123	-	Monitoring Undertake monitoring of air quality	0	On-going monitoring in the vicinity of a pad. Monitoring for combustion gasses (NOx, NO2, PM10 and also SO2, CO and VOCs).	Quant	MM	Possible - low	1	1	1	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Air Quality	N/A	16a	16a	124	-	Preparation of an emissions reduction plan (reduced emission completions) including an assessment of potential local air quality impacts including implications for compliance with ambient air quality limit values	0	Plan preparation only Develop emissions inventory for the site Undertake dispersion modelling of inventory to estimate concentrations within site boundaries and surrounding areas Undertake additional modelling of potential impacts of emissions from site on nearby population and/or sensitive habitats Identify and assess options for reducing	Quant	MH	No	1	1	1	1	1
Air Quality	N/A	17b	17b	125	-	Reduced emission completions (REC) to eliminate gas venting: prohibit venting of gas; capture and cleaning for use of gas released from fracture fluid and produced water	0	Capture and cleaning for use of gas released from fracture fluid and produced water	Quant	HH	No	1	1	1	1	1
Waste	N/A	N47	N47	126	-	Operator demonstrates availability of appropriate wastewater treatment facilities	0	0	Qual	LL	No	1	-	1	1	1
Waste	N/A	36c	36c	127	-	Treatment requirements for wastewater and capability of treatment works to treat wastewater established	0	0	Qual	LL	Possible - high	1	1	1	1	1
Waste	N/A	27c	27cii	128	-	Injection of flowback and produced water into designated formations for disposal, provided specific conditions are in place: i) treated waste water and ii) untreated wastewater	Untreated wastewater	0	Qual	LL	Possible - high	-	1	1	1	1
Waste	N/A	N50	N50	129	-	Lined open ponds with safety net protecting biodiversity	0	0	Qual	ML	No	1	1	1	1	1
Waste	N/A	27c	27c i	130	-	Injection of flowback and produced water into designated formations for disposal, provided specific conditions are in place: i) treated waste water and ii) untreated wastewater	Treated wastewater	0	Qual	MM	Possible - high	-	1	1	1	1
Waste	N/A	3b	3b xiii	131	-	Monitoring Undertake monitoring of drilling mud volumes and treatment	0	Analyse for VOCs, metals, total petroleum hydrocarbons, NORM.	Quant	MM	No	1	1	1	1	1
Waste	N/A	3b	3b xiv	132	-	Monitoring Undertake monitoring of flowback water return rate and characterise	0	Analyse for oil & grease, BTEX, VOCs, SVOCs, TDS, pH, sulphates, H2S, heavy metals, NORM, biocides, emulsion breakers, corrosion inhibitors	Quant	MM	Possible - high	1	1	1	1	1
Waste	N/A	3b	3b xv	133	-	Monitoring Undertake monitoring (volume and characterisation) of produced water volume and treatment solution	0	Analyse for oil & grease, BTEX, VOCs, SVOCs, TDS, pH, sulphates, H2S, heavy metals, NORM, biocides, emulsion breakers, corrosion inhibitors	Quant	MM	Possible - high	1	1	1	1	1
Waste	N/A	N53	N53	134	-	Consider wastewaters from unconventional gas operations as hazardous waste	0	0	Qual	MM	No	-	-	-	-	-
Waste	N/A	27f	27f	135	-	Operators keep records of all waste management operations and make them available for inspection (e.g. of flowback, produced water management)	0	0	Qual	LH	No	1	1	1	1	1
Waste	N/A	N51	N51	136	-	Consider wastewaters hazardous unless operator demonstrates otherwise	0	0	Qual	MH	No	1	-	1	-	1
Waste	N/A	N52	N52	137	-	Ban injection of wastewaters into geological formations for disposal	0	0	Qual	MH	No	-	-	-	-	-
Waste	N/A	30c	30c	138	-	Use of closed loop system to contain drilling mud	0	Closed-loop systems employ a suite of solids control equipment to minimise drilling fluid dilution and provide the economic handling of the drilling wastes. The closed loop system can include a series of linear-motion shakers, mud cleaners and centrifuges followed by a dewatering system. The combination of equipment typically results in a "dry" location where a reserve pit is not required, used fluids are recycled, and solid wastes can be land	Quant	HH	Possible - high	1	1	1	-	1
Post Closure	N/A	N22	N22	141	-	Maintain records of well location and depth indefinitely	0	0	Qual	LL	Yes	1	1	1	1	1
Post Closure	N/A	N11	N11	142	-	Operator to provide financial guarantee to competent authority to cover costs of any remedial action following transfer of responsibility	0	Required following transfer of responsibility as prior to that point in time, the operator remains responsible for remedial action.	Qual	LM	No	-	-	-	1	1
Post Closure	N/A	N12	N12	143	-	Operator to provide a financial contribution to the competent authority following closure and abandonment. This contribution should be sufficient to cover ongoing monitoring and related activities over a sufficient period [assume minimum of 20 years]	0	0	Qual	ML	No	-	-	-	1	1
Post Closure	N/A	26g	26g	144	-	Implementation of remedial measures if well failure occurs	0	Note - measure also listed under 'Underground risks'	Qual	MM	Possible - high	1	1	1	1	1
Post Closure	N/A	29a	29a	145	-	Good practice construction / deconstruction practices, including design for well abandonment	0	Note - also included in surface water ref. construction. Operators should apply construction industry good practice to prevent pollution of surface water through operator training and approach to construction practice	Qual	MM	Possible - high	-	1	1	1	1
Post Closure	N/A	N10	N10	146	-	Operator remain responsible for monitoring, reporting and corrective measures following well closure (or temporary well abandonment) and prior to transfer of responsibility to competent authority [assume minimum of 20 years]	0	Transfer of responsibility to occur	Qual	MM	No	-	-	-	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Post Closure	N/A	13d	13d ii	147	-	Abandonment survey Undertake sampling of surface water bodies near the pad	0	Surface water Sampling of surface water courses near the pad and analyse for suspended solids, BOD, dissolved oxygen, pH, ammonia, chloride also total petroleum hydrocarbons and polyaromatic hydrocarbons, radioactivity, fracturing chemicals and heavy metals for assurance.	Quant	MM	Possible - high	1	-	1	1	1
Post Closure	N/A	13d	13d iii	148	H	Abandonment survey Undertake sampling of groundwater near the pad	High Ambition	Groundwater Sampling of monitoring boreholes and analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals.	Quant	MM	Possible - high	1	-	1	1	1
Post Closure	N/A	13d	13d iv	149	-	Abandonment survey Obtain data on drinking water abstraction points (wells, boreholes, springs, surface water abstraction points	0	Drinking water abstraction points Obtain water quality data and water gas content from water abstraction points in the operational area (e.g. regarding dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals)	Quant	MM	Possible - high	1	-	1	1	1
Post Closure	N/A	13d	13d v	150	-	Abandonment survey Undertake land condition (soil) survey around pad	0	Land condition (soil) Establish land condition in immediate are of the pad and analyse for analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, asbestos, chloride	Quant	MM	Possible - high	1	-	1	1	1
Post Closure	N/A	13d	13d vi	151	-	Abandonment survey Undertake survey of biodiversity, ecology and invasive species survey	Assumed to be Middle Ambition	Scope will vary depending on presence of protected species and notable habitats and whether a designated site.	Quant	LL	No	1	-	1	-	1
Post Closure	N/A	13d	13d vii	152	-	Abandonment survey Undertake sampling for methane near surface in the pad location	0	0	Quant	MM	No	1	-	1	1	1
Post Closure	N/A	13d	13d viii	153	L	Abandonment survey Undertake assessment of landuse, infrastructure and buildings	LOW Undertake assessment of landuse, infrastructure and buildings through desk study	LOW AMBITION. Desk study and mapping of landuse, infrastructure and buildings. Objective is to enable comparison with baseline assessment and consequently any impacts.	Quant	LL	No	-	-	-	-	-
Post Closure	N/A	13d	13d viii	154	H	Abandonment survey Undertake assessment of landuse, infrastructure and buildings	HIGH Undertake assessment of landuse, infrastructure and buildings survey through desk study and aerial survey	HIGH AMBITION. As above plus remote (aerial) survey of land, land uses, structures etc. Objective is to enable comparison with baseline assessment and consequently any impacts.	Quant	MM	No	1	-	1	-	1
Post Closure	N/A	13d	13d ix	155	L	Abandonment survey Undertake assessment of ex-anti underground wells and structures	LOW Undertake assessment of underground wells and structures through desk study	LOW AMBITION. Check baseline list of penetrations into zone within area (from well history databases). Relates to wells and structures in place prior to UG activities.	Quant	LL	Possible - high	-	-	-	1	1
Post Closure	N/A	13d	13d ix	156	H	Abandonment survey Undertake assessment of ex-anti underground wells and structures	HIGH Undertake assessment of underground wells and structures desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells	HIGH AMBITION. As per LOW above plus: desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells. Relates to wells and structures in place prior to UG activities.	Quant	MM	No	-	-	-	-	-
Post Closure	N/A	12	12	157	-	Specific post closure risk assessment, well plugging, inspection and monitoring requirements (e.g. for releases to air, well integrity, periodicity of inspections, wellhead monitoring every 90 days)	0	Measure includes: Flush wells with a buffer fluid before plugging Plug wells. Use two cement plugs: one in producing formation and one for surface to bottom of drinking water level, fill the remainder with mud. Perform a mechanical integrity test prior to plugging to evaluate integrity of casing and	Quant	HH	Possible - high	1	1	1	1	1
Post Closure	N/A	13b	13b i	158	-	Specific post closure well inspection, maintenance and monitoring/reporting programme (i) following detection of possible pollution (low ambition); (ii) periodic inspection and monitoring (high ambition)	Post closure well inspection, maintenance and monitoring/reporting programme - following detection of possible pollution (low ambition)	Following detection of possible pollution and after well closure. Well inspection, maintenance and monitoring to ensure integrity. Reports would be prepared and submitted to competent authority by operators. Duration will be until licence surrender. Programme would include: - mechanical integrity testing (MIT) - determination of any necessary maintenance - submission of reports - implementation of remedial actions as necessary	Qual	LH	Possible - high	-	-	-	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Post Closure	N/A	13b	13b ii	159	-	Specific post closure well inspection, maintenance and monitoring/reporting programme (i) following detection of possible pollution (low ambition); (ii) periodic inspection and monitoring (high ambition)	Post closure well inspection, maintenance and monitoring/reporting programme - periodic inspection and monitoring (high ambition)	Well inspection, maintenance and monitoring to ensure integrity on a regular basis (e.g. 3 yearly). Reports would be prepared and submitted to competent authority by operators. Duration will be until licence surrender. Programme would include: - mechanical integrity testing (MIT) - determination of any necessary maintenance - submission of reports - implementation of remedial actions as necessary	Qual	MH	Possible - high	-	-	-	1	1
Post Closure	N/A	13c	13c	160	-	Ownership and liability of wells transferred to a competent authority on surrender of the site licence following a period of monitoring	0	Following a period of monitoring [minimum 20 years] after well/pad closure and subsequent site reinstatement, the site licence is surrendered and the ownership and liability of the wells is transferred to the appropriate competent authority in MSs. Following transfer, the competent authority takes on responsibility and liability for any resultant environmental damage linked to the	Qual	HH	No	-	-	-	1	1
Public Acceptance	N/A	N23	N23	161	-	Public disclosure by operators of environmental monitoring (baseline, operational and post closure), resource use (water use and chemicals), production, incidents (e.g. pollution events, well failure) and well integrity information	0	Operators would be required to publicly disclose baseline, ongoing monitoring and well integrity information through website establishment and maintenance and collation of information. Applies to baseline information through to transfer of responsibility to Competent Authority.	Qual	LL	Possible - low	1	-	1	1	1
Public Acceptance	N/A	15	15i	162	L	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) for permitting	LOW AMBITION. Engagement at permitting (website, information, public meetings) and abandonment and relinquishing of permits. (website and information).	Note aspects of public acceptance linked to chemicals are on the chemicals tab. The focus here is on wider public engagement.	Quant	LL	Possible - high	1	1	1	1	1
Public Acceptance	N/A	N41	N41	163	-	Member State Competent Authorities provide information on the licences and permits of operators involved in unconventional gas exploration and production	0	0	Quant	LL	No	-	-	-	1	1
Public Acceptance	N/A	N42	N42	164	-	Prohibit non-disclosure agreements between local residents and/or landowners and unconventional gas operators	0	0	Qual	LL	No	-	-	-	1	1
Public Acceptance	N/A	N40	N40	165	-	Member State Competent Authorities provide a map of planned and existing exploration, production and abandoned well locations	0	Also relevant to underground potentially	Quant	MM	No	1	-	1	-	1
Public Acceptance	N/A	15	15i	166	H	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) for permitting	HIGH AMBITION. As per low ambition PLUS the following: Early stage consultation (initial exploration, pre-site development and pre-permitting) consultation (website, information preparation, public meetings). Production stage ongoing consultation (ongoing website and information provision)	Note aspects of public acceptance linked to chemicals are on the chemicals tab. The focus here is on wider public engagement.	Quant	MM	Possible - low	-	-	-	1	1
Public Acceptance	N/A	N03	N03	167	-	All permits/authorisations/licences relating to environmental risk management to be made available to the public and included on a central data repository for all unconventional gas operations in the Member State / EU	0	0	Qual	MM	No	1	-	1	1	1
Public Acceptance	N/A	N04	N04	168	-	EU institutions and/or Member States provide peer reviewed information to the public on a regular basis on the current state of knowledge of potential environmental risks and benefits from unconventional gas and available measures to manage those risks	0	0	Qual	MM	No	-	-	-	-	-
Other Measures	sea	N34	N34	169	-	Public authorities produce an underground regional impact assessment to optimise resource allocation between unconventional gas and other underground resources (e.g. geothermal energy)	0	0	Quant	LL	No	1	-	1	1	1
Other Measures	permit	N35	N35	170	-	Member States implement integrated permitting for unconventional gas	0	0	Qual	LL	No	-	1	1	1	1
Other Measures	N/A	N25	N25	171	-	Reversal of the burden of proof for unconventional gas operators in the context of liability in case of environmental damage	0	0	Qual	LL	No	-	-	-	-	-
Other Measures	N/A	N38	N38	172	-	Maintain operator liability for any pollution arising from wells for a period of 100 years	0	0	Qual	LM	No	1	-	1	-	1
Other Measures	N/A	N39	N39	173	-	Maintain operator liability for any pollution arising from wells indefinitely	0	0	Qual	LM	No	1	-	1	-	1
Other Measures	operator	N28	N28	174	-	Assessment by the Competent Authority of the technical and financial capacity of an operator	0	0	Qual	LM	No	-	-	-	1	1
Other Measures	trans	59a	59a	175	-	Traffic impact assessment including consideration of noise, emissions and other relevant impacts	0	0	Quant	LM	Possible - high	1	-	1	1	1
Other Measures	operator	N29	N29	176	-	Financial guarantees by operators for environmental and civil liability covering any accidents or unintended negative impacts caused by their own activities or those outsourced to others (to cover incidents and accidents during and after operations, restoration of site)	0	0	Qual	LM	No	-	-	-	1	1
Other Measures	efficiency	N36	N36	177	-	Operators work together to ensure efficient provision of gas collection and wastewater treatment infrastructure	0	0	Qual	LM	No	-	-	-	-	-

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Other Measures	ecology	N21	N21	178	-	Implement precautions to prevent invasive species by cleaning vehicles	0	0	Qual	ML	No	-	-	-	-	-
Other Measures	permit	N15	N15	179	-	Mandatory EIA for all projects expected to involve hydraulic fracturing, before exploration starts	0	0	Quant	ML	No	1	1	1	-	1
Other Measures	permit	N16	N16 i	180	-	Mandatory EIA (i) after initial phase of well exploration and before first test fracturing, and (ii) before production commences	Mandatory EIA according to Directive 2011/92/EU after well exploration and before first test fracturing	0	Quant	ML	No	-	-	-	1	1
Other Measures	permit	N16	N16 ii	181	-	Mandatory EIA (i) after initial phase of well exploration and before first test fracturing, and (ii) before production commences	Mandatory EIA according to Directive 2011/92/EU before production commences	0	Quant	ML	No	-	-	-	1	1
Other Measures	permit	N17	N17	182	-	Assessment of whether full project is likely to have significant effects on the environment during prospecting phase (i.e. extending the existing requirement in relation to deep drillings under the EIA Directive to include screening prior to development of exploration plans/prospecting and taking account of the entire project)	0	0	Quant	ML	No	-	-	-	-	-
Other Measures	incident	N08	N08a	183	-	In the case of an incident/accident significantly affecting the environment: (a) operator informs competent authority immediately; (b) competent authority provides details of the circumstances of the incident and effects on the environment to a designated body at EU level who will make non-confidential information available to the public	In the case of an incident/accident significantly affecting the environment, operator to inform competent authority immediately.	0	Qual	ML	Possible - high	-	-	-	1	1
Other Measures	incident	N08	N08b	184	-	In the case of an incident/accident significantly affecting the environment: (a) operator informs competent authority immediately; (b) competent authority provides details of the circumstances of the incident and effects on the environment to a designated body at EU level who will make non-confidential information available to the public	In the case of an incident/accident significantly affecting the environment, competent authority to provide details of the circumstances of the incident and effects on the environment to a designated body at EU level who will make non-confidential information available to the public	0	Qual	ML	No	-	-	-	-	-
Other Measures	trans	59b	59b	185	-	Transport management plan (including consideration of available road, rail, waterway infrastructure)	0	0	Quant	MM	Possible - high	1	-	1	-	1
Other Measures	trans	60c	60c	186	-	Site selection close to water sources to minimise haulage requirements	0	0	Qual	MM	No	-	-	-	-	-
Other Measures	trans	61b	61b i	187	-	Minimise resources demands and hence traffic movements through (i) water management plans and (ii) wastewater management plans	i) water management plans to minimise water demands and hence traffic movements.	0	Qual	MM	No	1	-	1	1	1
Other Measures	trans	61b	61b ii	188	-	Minimise resources demands and hence traffic movements through (i) water management plans and (ii) wastewater management plans	ii) wastewater management plans to minimise water demands and hence traffic movements.	0	Qual	MM	No	1	-	1	1	1
Other Measures	trans	61c	61c	189	-	Site selection close to wastewater treatment / disposal facilities to minimise haulage requirements	0	0	Qual	MM	No	-	-	-	-	-
Other Measures	incident	N09	N09	190	-	Operator to develop and maintain a contingency plan to address foreseeable impacts of operating conditions on environmental risk management (e.g. degradation of well barriers, casing/cementing as per measure 22)	0	0	Quant	MM	Possible - low	1	-	1	1	1
Other Measures	noi	51a	51a	191	-	Maximum noise levels specified	0	0	Qual	MM	Possible - high	-	-	-	-	-
Other Measures	noi	51c	51c	192	-	Noise screening installation: (i) screen drilling and fracturing rigs with noise barrier / enclosure; (ii) acoustic fencing around the site perimeter.	0	Screen drilling and fracturing rigs with noise barrier/enclosure. Acoustic fencing around the site perimeter	Quant	MM	Possible - high	1	-	1	-	1
Other Measures	noi	51d	51d	193	-	Operational hours specified	0	(Noise abatement)	Qual	MM	Possible - low	1	-	1	-	1
Other Measures	noi	51e	51e	194	-	Vehicle routes specified	0	(Noise abatement)	Qual	MM	Possible - high	1	-	1	-	1
Other Measures	noi	51f	51f	195	-	Machinery orientation and selection to minimise noise	0	(Noise abatement)	Qual	MM	Possible - low	1	-	1	-	1
Other Measures	noi	3a	3a viii	196	-	Site baseline Undertake noise study	0	Consult with relevant regulatory authority and carry out baseline noise monitoring	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	noi	3b	3b viii	197	-	Monitoring Undertake monitoring of noise	0	0	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	monitor	N27	N27	198	-	Member States carry out strategic monitoring of unconventional gas activities at the level of the gas play to assess overall impacts and reaction as necessary	0	0	Quant	MM	No	1	-	1	1	1
Other Measures	guidance	N30	N30	199	-	The European Commission to develop further criteria/guidance for the assessment of environmental impacts from unconventional gas	0	0	Quant	MM	No	-	-	-	-	-
Other Measures	inspection	N31	N31	200	-	Inspections by Competent Authorities during all stages of development (e.g. of well completion reports and environmental risk management and controls)	0	0	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	skills	N32	N32	201	-	Competent Authorities have available sufficient inspection capacity and appropriately skilled inspectors	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	inspection	N33	N33	202	-	Independent inspection during all stages of development of well integrity	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	ecology	N37	N37	203	-	Pad construction activities staged to reduce soil erosion and to coincide with low rainfall periods	0	0	Qual	MM	No	-	-	-	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Other Measures	baseline	3a	3a iv	204	-	Site baseline Obtain data on drinking water abstraction points (wells, boreholes and springs)	0	Develop list of wells, boreholes, springs, surface water abstraction points within area (from public data). List names and depth of all potentially affected (by UG) underground sources of drinking water Provide geochemical information and maps/cross section on subsurface aquifers. Obtain water quality data and water gas content from existing available data.	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	monitor	3a	3a v	205	-	Site baseline Undertake land condition (soil) survey around pad	0	Trial pits and analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, asbestos, chloride.	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	trans	3a	3a vii	206	L	Site baseline Undertake transport and traffic study.	LOW AMBITION Undertake transport and traffic study. Liaise with highway authority and identify relevant routes to/from well pad	0	Quant	MM	Possible - high	1	-	1	-	1
Other Measures	trans	3a	3a vii	207	H	Site baseline Undertake transport and traffic study.	HIGH AMBITION Undertake transport and traffic study. As per LOW plus traffic survey and traffic modelling	0	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	ecology	3a	3a ix	208	-	Site baseline Undertake survey of biodiversity and ecology survey	Assumed to be Middle Ambition	Scope will vary depending on presence of protected species and notable habitats and whether a designated site.	Quant	MM	Possible - low	1	-	1	1	1
Other Measures	baseline	3a	3a xii	209	L	Site baseline Undertake assessment of landuse, infrastructure and buildings	LOW AMBITION. Undertake assessment of landuse, infrastructure and buildings through desk study	Desk study	Quant	MM	Possible - high	1	-	1	-	1
Other Measures	baseline	3a	3a xii	210	H	Site baseline Undertake assessment of landuse, infrastructure and buildings	HIGH AMBITION. As LOW plus remote (aerial) survey of land, land uses, structures etc.	0	Quant	MM	No	1	-	1	-	1
Other Measures	monitor	3b	3b iv	211	-	Monitoring Undertake monitoring of drinking water abstraction points (wells, boreholes, springs, surface water)	0	Obtain water quality data and water gas content from existing available data. Ongoing monitoring. Annual desk study using data from abstraction points	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	monitor	3b	3b v	212	-	Monitoring Undertake land condition (soil) tests every five years outside site boundary	0	Analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, chloride).	Quant	MM	No	1	-	1	-	1
Other Measures	trans	3b	3b vii	213	-	Monitoring Undertake monitoring of traffic numbers and patterns	0	Traffic count site/system to provide weekly or monthly counts.	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	monitor	3b	3b xi	214	-	Monitoring Undertake monitoring of energy source and use	0	0	Quant	MM	No	1	-	1	-	1
Other Measures	monitor	3b	3b xii	215	-	Monitoring Undertake monitoring of greenhouse gas emissions	0	0	Quant	MM	No	-	-	-	1	1
Other Measures	ecology	3b	3b xvi	216	-	Monitoring Undertake periodic surveys of biodiversity, ecology and invasive species	Assumed to be Middle Ambition	Scope and frequency will vary depending on presence of protected species and notable habitats and whether a designated site. Invasive species mitigation plan if required	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	incident	3b	3b xix	217	-	Monitoring Undertake monitoring of spills volume, nature, location and clean-up (including reporting)	0	0	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	cumulative	7	7	218	-	Cumulative effects (e.g. air pollution, traffic impacts, water resource requirements) of gas play development assessed in planning and permitting taking into account other (non-unconventional gas) developments and plans	0	Complimentary with other measures associated with planning. Linked to SEA	Qual	MM	No	-	-	-	1	1
Other Measures	permit	N02	N02	219	-	Operator, as part of permit conditions, obtains independent evaluation of environmental risk management measures for gas concession before fracturing commences and at regular intervals thereafter	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	permit	N06	N06	220	-	Operations to be subject to an integrated permit from the national authority, setting measures to manage environmental impacts for all environmental media (air surface/ground water, land). Combined monitoring and inspection regimes where separate competent authorities exist	0	0	Quant	MM	No	1	1	1	1	1
Other Measures	sea	N13	N13	221	-	Member States carry out SEA to set up plans/programmes setting the framework for unconventional gas projects before granting concessions for unconventional gas exploration and production and assess environmental effects of such plans. Assessment to address surface aspects such as water abstraction, waste treatment and disposal, transport, air quality, landtake, species diversity as well as known underground risks. Assessment to be reviewed before production commences on the basis of information obtained during the exploration phase. Those MS that have already granted concessions to perform	0	0	Quant	MM	No	-	-	-	1	1
Other Measures	equip	N18	N18	222	-	Ensure equipment is compatible with composition of fracturing chemicals	0	0	Qual	MM	Possible - high	1	-	1	-	1
Other Measures	equip	N19	N19	223	-	Carry out thorough planning and testing of equipment prior to hydraulic fracturing operations	0	0	Qual	MM	Possible - high	1	-	1	-	1
Other Measures	management	N20	N20	224	-	Environmental management system accreditation for unconventional gas installation operators	0	0	Quant	MM	No	1	-	1	-	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Other Measures	materi als	30e	30e	225	-	Muds restricted to approved list with known properties/safety data or non-toxic drilling muds	Restrict muds to approved list	Specify the use of muds from an approved list to minimise the risk of harmful (polluting) mud production which could result in polluting spills	Qual	MH	No	-	-	-	-	-
Other Measures	materi als	30e	30e	226	-	Muds restricted to approved list with known properties/safety data or non-toxic drilling muds	Restrict muds to non-toxic drilling muds	Specify the use of water-based muds/non-toxic chemical additives	Qual	HH	No	1	1	1	-	1
Other Measures	manag ement	29e	29e	227	-	Site reinstatement plan	0	Purpose of measure is to develop a reinstatement plan for the site following well closure and abandonment.	Quant	MH	Yes	1	-	1	1	1
Other Measures	inciden t	9b	9b	228	-	Emergency response plan developed and put in place covering: - leaks from the well to groundwater or surface water - releases of flammable gases from the well or pipelines - fires and floods - leaks and spillage of chemicals, flowback or produced water - releases during transportation	0	0	Qual	HM	Yes	-	1	1	1	1
Other Measures	inciden t	9a	9a	229	-	Consideration of major hazards for all stages in the life cycle of the development (early design, through operations to post abandonment) and development of HSE case or similar demonstrating adequacy of the design, operations and HSE management (including emergency response) for both safety and environmental major impacts	0	0	Qual	HH	Possible - high	1	1	1	1	1
Other Measures	trans	60a	60a	230	-	Use of temporary surface pipes for distribution of water supply	0	Temporary pipes laid above ground to supply water to pads.	Qual	HH	No	-	-	-	-	-
Other Measures	trans	60b	60b	231	-	Use of temporary surface pipes for collection of flowback	0	Temporary pipes laid above ground to collect flowback and transport to treatment plant.	Qual	HH	No	-	-	-	-	-
Other Measures	trans	61a	61a	232	-	Use of temporary surface pipes for collection of produced water	0	Temporary pipes laid above ground to collect produced water and transport to treatment plant.	Qual	HH	No	-	-	-	-	-

Non-BAU Measures in Policy Options

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Zoning	N/A	42b	42b	1	-	Location of sites close to existing pipeline infrastructure	0	Site selection takes into consideration existing gas pipeline infrastructure to enable minimisation of the need for additional pipeline infrastructure and associated development impacts	Qual	LL	No	1	-	1	-	1
Zoning	N/A	N48	N48	2	-	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers and the surface to be determined based on risk assessment	0	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	26c	26c	3	-	Fracturing to be a minimum distance from water resources	0	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	40c	40c	4	-	High land, agricultural and ecological value locations avoided	0	Assessment of and avoidance of high land, agricultural and ecological value locations (e.g. Natura 2000 sites, conservation sites).	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	5	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Buffer zone from abstraction points and aquifers of 1,000m for drinking water related abstraction	Applicable regardless of area type (i.e. not limited to Natura 2000 site and other specified sites). Hence applicability is broader.	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	6	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Buffer zone from residential areas, schools hospitals and other sensitive areas of 1,600m	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	7	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Buffer zone within which detailed noise assessment is required of 305m	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	8	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Buffer zone from abandoned wells and other potential pathways for fluid migration (distance specified on risk basis)	0	Qual	MM	No	1	-	1	-	1
Zoning	N/A	2f	2f	9	-	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells, active & abandoned mines and other potential pathways for fluid migration, and other sensitive areas	Additional containment for sites near surface water supply locations	This is required for sites within 800m of water supply locations in Colorado. The definition of additional containment is not provided - assume bunded tanks/site - see other measures re. this in surface water	Qual	MM	No	1	-	1	-	1
Zoning	N/A	40a	40a	10	-	Optimisation from an environmental perspective, i.e. the number of wells, pad density and pad spacing	0	Optimise the number of wells per pad, pad density and pad spacing to minimise cumulative environmental impacts (e.g. one pad per 2.6 km2 proposed by New York State). This will include consideration of siting with consideration of conflicts with nearby or adjacent sensitive land uses such as residences, schools, hospitals, available transport infrastructure, access to water supply, access to wastewater treatment, etc. Note: the acquis communautaire requires this measure, but it is uncertain whether it is	Qual	HM	No	1	-	1	-	1
Zoning	N/A	40b	40b	11	-	Compatibility with current and future potential landuse (Natura 2000 sites, conservation sites, human use, industrial use, appropriate zoning, CCS, geothermal, water abstraction)	0	Assessment of compatibility with current and future landuse plans (e.g. Natura 2000 sites, conservation sites, human use, industrial use, appropriate zoning. Note: the acquis communautaire requires this measure, notably as a mitigation measure under the SEAD/the EIAD, but without guarantee of the result, Natura2000 Directives	Qual	HM	No	1	-	1	-	1
Zoning	N/A	1b	1b	12	-	Restrict operations within and underneath specified sites (e.g. Natura 2000, protected sites, coal mining areas, drinking water protection areas, water extraction areas for public drinking water supply, mineral spa protection zones karstic aquifers, flood prone zones and mineral water reserves, reforestation areas and areas known to be unfavourable - with regard to potential environmental impacts) or within certain distances to specified sites	0	Operations would be restricted (i.e. greater controls as required by discretion of MS authorities) within specified areas. Areas known to be unfavourable - with regard to potential environmental impacts - geological and hydrogeological conditions (groundwater potentials and pathways, tectonically fractured rocks, artesian confined aquifers, suspected pathways introduced by abandoned boreholes	Qual	HM	Yes	1	-	1	-	1
Zoning	N/A	55e	55e	13	-	Avoid high seismicity risk areas	0	0	Qual	HH	No	1	-	1	-	1
Zoning	N/A	55i	55i	14	-	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers (e.g. 600m) and the surface (e.g. 600m depth requires special permit)	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers of, e.g. 600m	0	Qual	HH	No	1	-	1	-	1
Zoning	N/A	55i	55i	15	-	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers (e.g. 600m) and the surface (e.g. 600m depth requires special permit)	Special permit conditions where hydraulic fracture pipes are less than, e.g. 600m depth from surface	0	Qual	HH	No	1	-	1	-	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Zoning	N/A	1a	1a	16	-	Prohibit operations within and underneath specified sites (e.g. Natura 2000, protected sites, coal mining areas, drinking water protection areas, water extraction areas for public drinking water supply, mineral spa protection zones karstic aquifers, flood prone zones and mineral water reserves, reforestation areas and areas known to be unfavourable - with regard to potential environmental impacts) or within certain distances to specified sites	0	Areas known to be unfavourable - with regard to potential environmental impacts - geological and hydrogeological conditions (groundwater potentials and pathways, tectonically fractured rocks, artesian confined aquifers, suspected pathways introduced by abandoned boreholes or mining activities)	Qual	HH	Yes	1	-	1	-	1
Underground Risks	N/A	N44	N44	17	-	Competent authorities compile regional maps of underground resources	0	0	Qual	LL	No	1	-	1	-	1
Underground Risks	N/A	N55	N55	18	-	Conduct 2D seismic survey to identify faults and fractures.	0	0	Quant	LM	Yes	1	1	1	1	1
Underground Risks	N/A	28d	28d	19	-	Sharing of information to ensure that all operators in a gas play are aware of risks and can therefore plan	0	0	Qual	LM	Possible - low	1	1	1	1	1
Underground Risks	N/A	N45	N45	20	-	Members States establish a capability to address groundwater contamination arising from unconventional gas operations. In the case of transboundary aquifers, joint capability established	0	0	Qual	LM	No	1	-	1	-	1
Underground Risks	N/A	55g	55g	21	-	Engagement with third parties (e.g. regulators, other operators, researchers) to ensure fully aware of any issues / proximity (e.g. to other underground activities)	0	0	Qual	ML	Possible - low	1	-	1	-	1
Underground Risks	N/A	22d	22d	22	-	Search for and document potential leakage pathways (e.g. other wells, faults, mines)	0	Through delivery of 3 a x detail	Quant	MM	Possible - high	1	1	1	1	1
Underground Risks	N/A	26d	26d i	23	L	i) Development of a conceptual model of the zone before work commences covering geology, groundwater flows, pathways, microseismicity and subsequent updating of the model as information becomes available ii) as above plus Modelling of the impact of groundwater pumping on linked groundwater and surface water flows and quality	Related to 3a x-a4 (which is Low Ambition)	Through delivery of 3 a x detail	Quant	MM	No	-	-	-	-	-
Underground Risks	N/A	26d	26d ii	24	-	i) Development of a conceptual model of the zone before work commences covering geology, groundwater flows, pathways, microseismicity and subsequent updating of the model as information becomes available ii) as above plus Modelling of the impact of groundwater pumping on linked groundwater and surface water flows and quality	As 26d I + Modelling of the impact of groundwater pumping on linked groundwater and surface water flows and quality	Through delivery of 3 a x detail	Quant	MM	No	1	1	1	1	1
Underground Risks	N/A	26e	26e	25	-	Modelling of fracturing programme to predict extent of fracture growth based on best information	0	Application of Discrete Fracture Network (DFN) approach including dynamic response (e.g. hydro-shearing), Finite Element Analysis (FEA) or Discrete Element Method (DEM). 3D fracture modelling integrated with geomechanics modelling	Quant	MM	No	1	-	1	1	1
Underground Risks	N/A	26g	26g	26	-	Implementation of remedial measures if well failure occurs	0	0	Qual	MM	Yes	1	1	1	1	1
Underground Risks	N/A	55c	55c	27	-	Ground motion prediction models to assess the potential impact of induced earthquakes	0	0	Quant	MM	No	-	-	-	-	-
Underground Risks	N/A	N09	N09	28	-	Operator to develop and maintain a contingency plan to address foreseeable impacts of operating conditions on environmental risk management (e.g. degradation of well barriers, casing/cementing as per measure 22)	0	0	Quant	MM	No	-	-	-	1	1
Underground Risks	N/A	N05	N05	29	-	Initiate immediate flowback post fracturing	0	0	Qual	MM	No	1	1	1	-	1
Underground Risks	N/A	N46	N46	30	-	The European Commission develops criteria/guidance for underground risk assessment (such as criteria to assess potential risks of groundwater contamination and induced seismicity) related to unconventional gas	0	0	Qual	MH	No	-	-	-	-	-
Underground Risks	N/A	N07	N07	31	-	Operator to use alternative fracturing fluids to water (e.g. nitrogen, CO2, propane)	0	0	Qual	MH	No	-	-	-	-	-
Underground Risks	N/A	55h	55h	32	-	Smaller preinjection prior to main operations to enable induced seismicity response to be assessed	0	Mini-fractures area carried out prior to full scale fracturing. Monitoring of the seismic response to the mini-fractures is carried out and assessment of the location's actual response compared with the modelled response is made. Analysis of results and conclusion drawn regarding suitability of and approach to full scale operations. Enables model predictions to be verified and the actual response of geological formations to be assessed.	Qual	MH	No	1	-	1	-	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Underground Risks	N/A	22a	22a	33	-	Key elements to maintain well safety such as: • blowout preventers • pressure & temperature monitoring and shutdown systems • fire and gas detection • continuous monitoring for leaks and release of gas and liquids • modelling to aid well/HF design • isolate underground source of drinking water prior to drilling • ensure micro-annulus is not formed • casing centralizers to centre casing in hole • select corrosive resistant alloys and high strength steel • fish back casing • maintain appropriate bending radius • triple casing • casing and cementing designed to sustain high pressure and low magnitude seismicity • isolation of the well from aquifers • casings: minimum distance the surface casing extends below aquifer (e.g. 30m below the deepest underground source of drinking water encountered while drilling the well, ref. Environment Agency 2012) and surface casing cemented before reaching depth of e.g. 75m below underground drinking water (ref. AEA 2012). Production casing cemented up to at least 150 metres above the formation where hydraulic	0	Measures to be split out for cost purposes	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b i	34	-	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	i) wireline logging (calliper, cement bond, variable density)	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b ii	35	-	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b iii	36	-	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	iii) mechanical integrity testing of equipment (MIT)	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b iv	37	-	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: i) wireline logging (calliper, cement bond, variable density) ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing iii) mechanical integrity testing of equipment (MIT) iv) casing inspection test and log	iv) casing inspection test and log	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22c	22c	38	-	Multiple barriers between the target formation and people/the environment, including minimum vertical distance between target formation and aquifers	0	0	Qual	HH	No	1	1	1	-	1
Underground Risks	N/A	26f	26f	39	-	Monitoring and control during operations to ensure hydraulic fractures / pollutants do not extend beyond the gas-producing formations and does not result in seismic events or damage to buildings/installations that could be the result of fracturing	0	Linked to 3 b xvii	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3a	3a xi	40	-	Site baseline Establish the presence of methane in groundwater, including drinking water	0	0	Quant	MM	Yes	1	1	1	1	1
Underground Risks	N/A	55d	55d	41	L	Microseismicity monitoring and management requirements during operations	LOW AMBITION Real time monitoring of microseismicity during all operations	Linked to 3 b xvii	Quant	MM	No	-	1	1	1	1
Underground Risks	N/A	55d	55d	42	-	Microseismicity monitoring and management requirements during operations	HIGH AMBITION AS LOW plus cessation of fracturing if specified induced seismic activity is detected (using traffic light system)	0	Qual	HH	No	1	1	1	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Underground Risks	N/A	3a	3a iii	43	L	Site baseline Undertake sampling of groundwater	MEDIUM AMBITION Sampling of shallow groundwater during wet and dry periods (cost is shown in Middle Ambition column)	Concentrate boreholes near pad (as on impacts on groundwater due to surface spills greatest near pad). Boreholes, at 15m depth at each corner. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals.	Quant	MM	Yes	-	-	-	-	-
Underground Risks	N/A	3a	3a iii	44	H	Site baseline Undertake sampling of groundwater	HIGH AMIBITION Borehole to sample deep groundwater and characterise the hydrological series (cost is shown in High Ambition column)	Deep boreholes in area. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals.	Quant	HH	Possible - low	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a1	45	-	Site baseline Geological, hydrogeological and seismic conceptual model [1] Obtain and analyze seismic (earthquake) history	0	0	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a2	46	L	Site baseline Geological, hydrogeological and seismic conceptual model [2] Obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures	LOW AMBITION. Undertake desk study based on existing data and literature	0	Quant	MH	Yes	-	-	-	-	-
Underground Risks	N/A	3a	3a x-a2	47	H	Site baseline Geological, hydrogeological and seismic conceptual model [2] Obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures	HIGH AMBITION. In addition LOW obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures through new cores and stratigraphic tests	0	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a3	48	-	Site baseline Geological, hydrogeological and seismic conceptual model [3] Undertake surface microseismic survey	0	0	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a4	49	L	Site baseline Geological, hydrogeological and seismic conceptual model [4] Undertake complex modelling of fluid flows and migration (reservoir simulations)	LOW AMBITION. Modelling over 100 years	0	Quant	MH	No	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a4	50	H	Site baseline Geological, hydrogeological and seismic conceptual model [4] Undertake complex modelling of fluid flows and migration (reservoir simulations)	HIGH AMBITION. Modelling is done over 10,000 years	0	Quant	HH	No	-	-	-	-	-
Underground Risks	N/A	3a	3a x-a5	51	-	Site baseline Geological, hydrogeological and seismic conceptual model [5] Develop maps and cross sections of local geologic structure	0	0	Quant	HH	Possible - low	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a6	52	H	Site baseline Geological, hydrogeological and seismic conceptual model [6] Conduct 3D seismic survey to identify faults and fractures	0	0	Quant	HH	Possible - low	1	1	1	1	1
Underground Risks	N/A	3a	3a x-a7	53	-	Site baseline Geological, hydrogeological and seismic conceptual model [7] Obtain data on area, thickness, capacity, porosity and permeability of formations	0	0	Quant	HH	Possible - high	1	1	1	1	1
Underground Risks	N/A	3a	3a xiii	54	L	Site baseline Undertake assessment of existing underground wells and structures	LOW AMBITION. Undertake assessment of underground wells and structures	Develop list of penetrations into zone within area (from well history databases).	Quant	MH	Possible - high	-	-	-	-	-
Underground Risks	N/A	3a	3a xiii	55	H	Site baseline Undertake assessment of existing underground wells and structures	HIGH AMBITION. As LOW AMBITION plus undertake assessment of underground wells and structures desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells	0	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3b	3b iii	56	L	Monitoring Undertake monitoring of groundwater	MEDIUM AMBITION Sampling of shallow groundwater during wet and dry periods	Concentrate boreholes near pad (as on impacts on groundwater due to surface spills greatest near pad). Boreholes, at 15m depth at each corner. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals.	Quant	MM	Yes	-	-	-	-	-
Underground Risks	N/A	3b	3b iii	57	H	Monitoring Undertake monitoring of groundwater	HIGH AMBITION Deep groundwater sampling network to determine the characteristics of deep groundwater and formation water and piezometric levels	Deep boreholes network in area. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3b	3b xvii	58	-	Monitoring Undertake monitoring of induced seismicity from fracturing	0	0	Quant	HH	No	1	1	1	1	1
Underground Risks	N/A	3b	3b xviii	59	-	Monitoring Undertake monitoring for presence of methane seepages in groundwater, including drinking water	0	0	Quant	HH	Possible - low	-	-	-	-	-

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Chemical Use	N/A	CSL5	CSL5	60	-	Authorities to organise an exchange of views/information on environmentally safer technologies and alternatives to the use of chemicals in hydraulic fracturing	0	0	Qual	LL	No	1	-	1	-	1
Chemical Use	N/A	N24	N24	61	-	Traceability of chemicals used by an operator	0	0	Qual	LL	No	-	-	-	-	-
Chemical Use	N/A	CAL1	CAL1	62	-	CSA/risk assessment explicitly specific to hydraulic fracturing in the EU to be included in REACH Registration	Chemicals - assessment	Cost to be estimated based on existing data in #11.	Quant	ML	No	-	-	-	-	-
Chemical Use	N/A	CAL2	CAL2	63	-	Develop a peer-reviewed EU-level exposure scenario / SpERC for HF for different chemical types	Chemicals - assessment	Estimated cost of developing SpERC to similar level of detail to those that already exist for e.g. additives used in petroleum products (CONCAWE/ESIG) http://www.cefic.org/Industry-support/Implementing-reach/Guidances-and-Tools1/	Quant	ML	No	1	-	1	-	1
Chemical Use	N/A	CAL3	CAL3	64	-	CAL2 to be implemented in CSAs for chemicals used in HF and any deviations explained	Chemicals - assessment	Should be feasible to estimate additional cost of UG company doing their own CSA for this specific use for typical number of chemicals used	Quant	ML	No	1	-	1	-	1
Chemical Use	N/A	CDL1	CDL1	65	-	Disclosure of information to Competent Authority: declaration of substance name and CAS number for the chemical substances potentially to be used in hydraulic fracturing. Per concession/play	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity)	Qual	ML	No	1	-	1	1	1
Chemical Use	N/A	CDL2	CDL2	66	-	Disclosure of information to the public: list of chemicals potentially to be used in hydraulic fracturing by UG company to be made available (e.g. via company website or centralised data dissemination portal). Per concession/play	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity)	Qual	ML	Possible - high	1	-	1	1	1
Chemical Use	N/A	CSL1a	CSL1a	67	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A or 1B	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL1b	CSL1b	68	-	Non-use in biocidal products of any substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A or 1B	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL1c	CSL1c	69	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as aquatic acute category 1 or aquatic chronic category 1	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL1d	CSL1d	70	-	Non-use in biocidal products of any substances with [harmonised or notified] classification as aquatic acute category 1 or aquatic chronic category 1	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL2	CSL2	71	-	Non-use of any substances on REACH Candidate List for authorisation (substances of very high concern)	Chemicals - selection	Too many substances potentially used in HF to robustly estimate differences in costs. Impacts on well productivity will far outweigh differences in prices of fluid additives	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL3	CSL3	72	-	Negative list of named substances that must not be used in UG extraction (alternative to two measures CSL1 and CSL2)	Chemicals - selection	Partially quantitative. Potential to cost actually developing the list but costs of not using substances on that list not quantifiable as per measures above	Quant	LM	No	1	1	1	1	1
Chemical Use	N/A	CSL4	CSL4	73	-	Demonstration that all steps practicable have been taken to reduce number, concentration and volume of chemicals used in hydraulic fracturing	Chemicals - selection	Not considered feasible to quantify costs as too site-specific.	Qual	ML	No	1	1	1	1	1
Chemical Use	N/A	CSM4	CSM4	74	-	Establish general principles for the use of chemicals (minimise use, substitution by less hazardous substances), oblige operator to present and discuss alternative substances and establish third party verification.	Chemicals - selection	0	Qual	LM	No	1	1	1	1	1
Chemical Use	N/A	CAM1	CAM1	75	-	Chemical safety assessment / biocide risk assessment includes assessment of risks of potential transformation products in HF / underground context, as part of permit/licence, with risk management measures implemented accordingly	Chemicals - assessment	Could be e.g. 2-3 times cost for standard CSA / risk assessment?	Quant	MM	No	-	-	-	-	-
Chemical Use	N/A	CSM2	CSM2	76	-	Positive list of substances expected to be safe under EU UG extraction conditions and require operators to only use substances on this positive list	Chemicals - selection	Partially quantitative. Potential to cost actually developing the list but costs of only using substances on that list not quantifiable as per measures above	Quant	MM	No	1	1	1	1	1
Chemical Use	N/A	CSM3	CSM3	77	-	Selection of substances (chemicals and proppants) that minimise the need for treatment when present in flowback water	Chemicals - selection	Not considered feasible to quantify costs as insufficient data on which substances (from a very large list) require more/less treatment under different circumstances	Qual	MM	No	1	1	1	1	1
Chemical Use	N/A	3b	3b x	78	-	Monitoring Undertake monitoring of chemicals type and volume used including record keeping	0	0	Quant	MM	Possible - low	1	-	1	1	1
Chemical Use	N/A	CSM1a	CSM1a	79	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A, 1B or 2	Chemicals - selection	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A, 1B or 2	Qual	LH	No	1	1	1	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Chemical Use	N/A	CSM1b	CSM1b	80	-	Non-use in biocidal products of any substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A, 1B or 2	Chemicals - selection	Non-use in biocidal products of any substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A, 1B or 2	Qual	LH	No	1	1	1	1	1
Chemical Use	N/A	CSM1c	CSM1c	81	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as aquatic acute category 1 or 2 or aquatic chronic category 1 or 2	Chemicals - selection	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as aquatic acute category 1 or 2 or aquatic chronic category 1 or 2	Qual	LH	No	1	1	1	1	1
Chemical Use	N/A	CSM1d	CSM1d	82	-	Non-use in biocidal products of any substances with [harmonised or notified] classification as aquatic acute category 1 or 2 or aquatic chronic category 1 or 2	Chemicals - selection	Non-use in biocidal products of any substances with [harmonised or notified] classification as aquatic acute category 1 or 2 or aquatic chronic category 1 or 2	Qual	LH	No	1	1	1	1	1
Chemical Use	N/A	CDM1	CDM1	83	-	Disclosure of information to Competent Authority: declaration of substance name, CAS number, precise concentrations, quantities and all physicochemical and (eco)toxicological data for the substances potentially to be used in hydraulic fracturing. Also potentially e.g. date of fracturing, total volume of fluids, type and amount of proppant; description of the precise additive purpose; concentration in the total volume. Per well. Prior to and after operations	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity).	Qual	HL	Possible - high	1	-	1	1	1
Chemical Use	N/A	CDM2	CDM2	84	-	Disclosure of information to public: list of chemicals and CAS numbers used to be made available (e.g. via company website and centralised data dissemination portal) for the chemicals potentially to be used in hydraulic fracturing. Per concession/play. Prior to and after operations	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity).	Qual	HL	No	1	-	1	1	1
Chemical Use	N/A	N26	N26	85	-	Select proppants which minimise the HVHF treatment required	0	0	Qual	MH	No	1	1	1	1	1
Chemical Use	N/A	CAH1	CAH1	86	-	Chemical safety assessment / biocide risk assessment includes assessment of risks of mixtures of chemicals used in HF as part of permit/licence, with risk management measures implemented accordingly. To include potential additive or synergistic impacts	Chemicals - assessment	Scientifically challenging and not likely to be possible to quantify with any degree of certainty.	Qual	HM	No	-	-	-	-	-
Chemical Use	N/A	CDH1	CDH1	87	-	Disclosure of information to public: details of substance name, CAS number, concentrations, and all physicochemical and (eco)toxicological data for the substances potentially to be used in hydraulic fracturing. This is to be made available (e.g. via company website and centralised data dissemination portal). Also potentially e.g. date of fracturing, total volume of fluids, type and amount of proppant; description of the overall purpose of the additives; concentration in the total volume. Per well. Prior to and after operations	Chemicals - disclosure	Is in principle possible to quantify but not considered proportionate to do this given costs of this are likely to be small and main costs are likely to arise due to other implications (e.g. Reduced options for chemical use due to greater scrutiny potentially leading to reduced productivity).	Qual	HM	Possible - low	1	-	1	1	1
Chemical Use	N/A	CSH2a	CSH2a	88	-	Non-use of any (non-biocidal) substances with [harmonised or notified] classification for any health or environmental effects	Chemicals - selection	0	Qual	MH	No	1	1	1	1	1
Chemical Use	N/A	CSH2b	CSH2b	89	-	Non-use in biocidal products of any substances with [harmonised or notified] classification for any health or environmental effects	Chemicals - selection	0	Qual	MH	No	1	1	1	1	1
Chemical Use	N/A	CSH1	CSH1	90	-	Use of water or inert materials only in hydraulic fracturing	Chemicals - selection	Not thought to be practicable and likely to have significant impact on viability and productivity of UG extraction. Not considered practical to quantify costs - main impact will be on well productivity, maintenance frequency, etc.	Qual	HH	No	1	1	1	1	1
Water Depletion	N/A	38a	38a i	91	-	i) Notification of water demand from fracturing operations to relevant water utilities and competent authorities	0	Inform relevant authorities (i.e. water utilities, environmental regulators, planning authorities) of water demand for the lifetime of the project.	Qual	LM	No	1	1	1	1	1
Water Depletion	N/A	38a	38a ii	92	-	ii) Notification of water demand from fracturing operations to relevant water utilities and competent authorities - high ambition (CBM only)	0	Inform relevant authorities (i.e. water utilities, environmental regulators, planning authorities) of water demand for the lifetime of the project (linked to fracturing) and submit groundwater pumping plans to relevant authorities to enable impacts of groundwater pumping to be understood on areas that are also used for groundwater resources.	Qual	LM	No	1	1	1	1	1
Water Depletion	N/A	38b	38b	93	-	Demand profile for water	0	Establish the water demand pattern taking account of number of wells, pad locations, drilling sequence, water consumption per unit operation. Establish flow patterns including peak and average flow volumes under a variety of scenarios	Quant	LM	Possible - high	1	-	1	-	1
Water Depletion	N/A	N49	N49	94	-	Strategic planning and staged approach of play development to avoid peaks in water demand	0	0	Qual	MM	No	1	-	1	-	1
Water Depletion	N/A	38c	38c	95	-	Water management plan	0	Develop a water management plan to cover water supply and efficient use on site.	Qual	MM	Possible - high	1	-	1	-	1
Water Depletion	N/A	3a	3a vi	96	-	Site baseline Establish water source availability and test for suitability	0	Locate water sources and identifying availability, water rights. Test water sources for suitability	Quant	MM	Possible - high	1	-	1	-	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Water Depletion	N/A	3b	3b vi	97	-	Monitoring Water resources availability	0	0	Quant	MM	No	1	1	1	1	1
Water Depletion	N/A	3b	3b ix	98	-	Monitoring Undertake monitoring of water volumes and origin	0	0	Quant	MM	No	1	-	1	-	1
Water Depletion	N/A	38d	38d	99	-	Reuse of flowback and produced water for fracturing	0	Reuse flowback and/or produced water to make up fracture fluid.	Quant	MM	No	1	-	1	1	1
Water Depletion	N/A	38e	38e	100	-	Use of lower quality water for fracturing (e.g. non-potable ground / surface water, rainwater harvesting, saline aquifers, sea water, treated industrial waterwaters)	0	Use lower quality water (non-potable) to make up fracture fluid.	Qual	MM	No	1	1	1	-	1
Surface Water	N/A	33i	33i	101	-	Good site security	0	Operators would be required to ensure that the site is protected properly to prevent vandalism that may lead to pollution from damaged equipment/infrastructure	Quant	ML	Yes	-	-	-	-	-
Surface Water	N/A	29a	29a	102	-	Good practice construction / deconstruction practices, including design for well abandonment	0	Note - also included in post closure ref. demolition. Operators should apply construction industry good practice to prevent pollution of surface water through operator training and approach to construction practice	Qual	MM	Possible - high	1	1	1	1	1
Surface Water	N/A	33a	33a	103	-	Good site practice to prevention of leaks and spills	0	0	Qual	MM	Yes	1	1	1	1	1
Surface Water	N/A	33d	33d	104	-	Spill kits available for use	0	0	Quant	MM	Yes	1	1	1	1	1
Surface Water	N/A	3a	3a ii	105	H	Site baseline Undertake sampling of surface water bodies in wet and dry periods	High Ambition	Analyse for suspended solids, BOD, dissolved oxygen, pH, ammonia, chloride also total petroleum hydrocarbons and polyaromatic hydrocarbons, radioactivity, fracturing chemicals and heavy metals for assurance.	Quant	MM	Possible - low	1	1	1	1	1
Surface Water	N/A	3b	3b ii	106	L	Monitoring Undertake monitoring of surface water bodies in wet and dry periods	LOW AMBITION Monitoring Undertake monitoring of surface water bodies in wet and dry periods	Analyse for suspended solids, BOD, dissolved oxygen, pH, ammonia, chloride also total petroleum hydrocarbons and polyaromatic hydrocarbons, radioactivity, fracturing chemicals and heavy metals for assurance.	Quant	MM	Possible - high	-	1	1	1	1
Surface Water	N/A	3b	3b ii	107	H	Monitoring Undertake monitoring of surface water bodies in wet and dry periods	HIGH AMBITION AS LOW AMBITION with alert system promoting corrective action	0	Quant	MH	No	1	-	1	-	1
Surface Water	N/A	33e	33e	108	-	Berm around site boundary	0	0	Quant	HM	No	1	1	1	-	1
Surface Water	N/A	33g	33g	109	-	Collection and control of surface runoff	0	Operators construct sites to effectively collect and control stormwater, e.g. draining to a single collection point, to enable effective control and management of any spills and leaks.	Quant	MH	Possible - high	1	-	1	1	1
Surface Water	N/A	29c	29c	110	-	Bunding of fuel tanks	0	0	Quant	HH	No	1	-	1	-	1
Surface Water	N/A	30d	30d	111	-	Use of closed tanks for mud storage	0	0	Quant	HH	Possible - low	-	-	-	-	-
Surface Water	N/A	33b	33b	112	-	Use of tank level alarms	0	For chemicals, fracturing fluid, muds and wastewaters. Activation triggers corrective action/contingency plan implementation.	Quant	HH	Possible - high	1	1	1	1	1
Surface Water	N/A	33c	33c	113	H	Use of double skinned closed storage tanks	High Ambition	For chemicals, fracturing fluid, muds and wastewaters	Quant	HH	No	1	1	1	1	1
Surface Water	N/A	33f	33f	114	-	Impervious site liner under pad with puncture proof underlay	0	0	Quant	HH	Yes	1	-	1	1	1
Air Quality	N/A	59d	59d	115	-	Use of vehicles (water, chemicals, waste trucking) that meet minimum air emission standards e.g. EURO standards	0	0	Qual	LL	No	-	-	-	-	-
Air Quality	N/A	N54	N54	116	-	Encourage industry voluntary approach to reduce air pollutants and greenhouse gases	0	0	Qual	LM	No	1	-	1	-	1
Air Quality	N/A	16b	16b i	117	-	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	Low emission power supply (switching to LPG)	0	Quant	LM	No	1	-	1	-	1
Air Quality	N/A	16b	16b ii	118	-	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	Low emission power supply (switching to grid electricity)	0	Quant	LM	No	1	-	1	-	1
Air Quality	N/A	16d	16d	119	-	Application of abatement techniques to minimise emissions (assumed SCR for NOx and Diesel Particulate Filter (DPF) for PM).	0	SCR for NOx Diesel Particulate Filter (DPF) for PM	Quant	LM	No	1	-	1	-	1
Air Quality	N/A	17c	17c	120	L	Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network)	LOW AMBITION Flares or incinerators to reduce emissions from fracturing fluid at exploration stage	Capture gas from fracture fluid at exploration stage and flare or incinerate	Quant	MM	Yes	-	-	-	-	-
Air Quality	N/A	17c	17c	121	H	Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network)	HIGH AMBITION As LOW AMBITION with no audible or visible flaring	0	Quant	MM	No	-	-	-	-	-

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Air Quality	N/A	3a	3a i	122	-	Site baseline Undertake sampling of air quality	0	Three month monitoring period to establish baseline using passive monitoring techniques at circa six points in the vicinity of a pad. Monitoring for combustion gasses (NOx, NO2, PM10 and also SO2, CO and VOCs).	Quant	MM	Possible - high	1	1	1	1	1
Air Quality	N/A	3b	3b i	123	-	Monitoring Undertake monitoring of air quality	0	On-going monitoring in the vicinity of a pad. Monitoring for combustion gasses (NOx, NO2, PM10 and also SO2, CO and VOCs).	Quant	MM	Possible - low	1	1	1	1	1
Air Quality	N/A	16a	16a	124	-	Preparation of an emissions reduction plan (reduced emission completions) including an assessment of potential local air quality impacts including implications for compliance with ambient air quality limit values	0	Plan preparation only Develop emissions inventory for the site Undertake dispersion modelling of inventory to estimate concentrations within site boundaries and surrounding areas Undertake additional modelling of potential impacts of emissions from site on nearby population and/or sensitive habitats Identify and assess options for reducing	Quant	MH	No	1	1	1	1	1
Air Quality	N/A	17b	17b	125	-	Reduced emission completions (REC) to eliminate gas venting: prohibit venting of gas; capture and cleaning for use of gas released from fracture fluid and produced water	0	Capture and cleaning for use of gas released from fracture fluid and produced water	Quant	HH	No	1	1	1	1	1
Waste	N/A	N47	N47	126	-	Operator demonstrates availability of appropriate wastewater treatment facilities	0	0	Qual	LL	No	1	-	1	1	1
Waste	N/A	36c	36c	127	-	Treatment requirements for wastewater and capability of treatment works to treat wastewater established	0	0	Qual	LL	Possible - high	1	1	1	1	1
Waste	N/A	27c	27cii	128	-	Injection of flowback and produced water into designated formations for disposal, provided specific conditions are in place: i) treated waste water and ii) untreated wastewater	Untreated wastewater	0	Qual	LL	Possible - high	-	1	1	1	1
Waste	N/A	N50	N50	129	-	Lined open ponds with safety net protecting biodiversity	0	0	Qual	ML	No	1	1	1	1	1
Waste	N/A	27c	27c i	130	-	Injection of flowback and produced water into designated formations for disposal, provided specific conditions are in place: i) treated waste water and ii) untreated wastewater	Treated wastewater	0	Qual	MM	Possible - high	-	1	1	1	1
Waste	N/A	3b	3b xiii	131	-	Monitoring Undertake monitoring of drilling mud volumes and treatment	0	Analyse for VOCs, metals, total petroleum hydrocarbons, NORM.	Quant	MM	No	1	1	1	1	1
Waste	N/A	3b	3b xiv	132	-	Monitoring Undertake monitoring of flowback water return rate and characterise	0	Analyse for oil & grease, BTEX, VOCs, SVOCs, TDS, pH, sulphates, H2S, heavy metals, NORM, biocides, emulsion breakers, corrosion inhibitors.	Quant	MM	Possible - high	1	1	1	1	1
Waste	N/A	3b	3b xv	133	-	Monitoring Undertake monitoring (volume and characterisation) of produced water volume and treatment solution	0	Analyse for oil & grease, BTEX, VOCs, SVOCs, TDS, pH, sulphates, H2S, heavy metals, NORM, biocides, emulsion breakers, corrosion inhibitors.	Quant	MM	Possible - high	1	1	1	1	1
Waste	N/A	N53	N53	134	-	Consider wastewaters from unconventional gas operations as hazardous waste	0	0	Qual	MM	No	-	-	-	-	-
Waste	N/A	27f	27f	135	-	Operators keep records of all waste management operations and make them available for inspection (e.g. of flowback, produced water management)	0	0	Qual	LH	No	1	1	1	1	1
Waste	N/A	N51	N51	136	-	Consider wastewaters hazardous unless operator demonstrates otherwise	0	0	Qual	MH	No	1	-	1	-	1
Waste	N/A	N52	N52	137	-	Ban injection of wastewaters into geological formations for disposal	0	0	Qual	MH	No	-	-	-	-	-
Waste	N/A	30c	30c	138	-	Use of closed loop system to contain drilling mud	0	Closed-loop systems employ a suite of solids control equipment to minimise drilling fluid dilution and provide the economic handling of the drilling wastes. The closed loop system can include a series of linear-motion shakers, mud cleaners and centrifuges followed by a dewatering system. The combination of equipment typically results in a "dry" location where a reserve pit is not required, used fluids are recycled, and solid wastes can be land	Quant	HH	Possible - high	1	1	1	-	1
Post Closure	N/A	N22	N22	141	-	Maintain records of well location and depth indefinitely	0	0	Qual	LL	Yes	1	1	1	1	1
Post Closure	N/A	N11	N11	142	-	Operator to provide financial guarantee to competent authority to cover costs of any remedial action following transfer of responsibility	0	Required following transfer of responsibility as prior to that point in time, the operator remains responsible for remedial action.	Qual	LM	No	-	-	-	1	1
Post Closure	N/A	N12	N12	143	-	Operator to provide a financial contribution to the competent authority following closure and abandonment. This contribution should be sufficient to cover ongoing monitoring and related activities over a sufficient period [assume minimum of 20 years]	0	0	Qual	ML	No	-	-	-	1	1
Post Closure	N/A	26g	26g	144	-	Implementation of remedial measures if well failure occurs	0	Note - measure also listed under 'Underground risks'	Qual	MM	Possible - high	1	1	1	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Post Closure	N/A	29a	29a	145	-	Good practice construction / deconstruction practices, including design for well abandonment	0	Note - also included in surface water ref. construction. Operators should apply construction industry good practice to prevent pollution of surface water through operator training and approach to construction practice	Qual	MM	Possible - high	-	1	1	1	1
Post Closure	N/A	N10	N10	146	-	Operator remain responsible for monitoring, reporting and corrective measures following well closure (or temporary well abandonment) and prior to transfer of responsibility to competent authority [assume minimum of 20 years]	0	Transfer of responsibility to occur	Qual	MM	No	-	-	-	1	1
Post Closure	N/A	13d	13d ii	147	-	Abandonment survey Undertake sampling of surface water bodies near the pad	0	Surface water Sampling of surface water courses near the pad and analyse for suspended solids, BOD, dissolved oxygen, pH, ammonia, chloride also total petroleum hydrocarbons and polyaromatic hydrocarbons, radioactivity, fracturing chemicals and heavy metals for assurance.	Quant	MM	Possible - high	1	-	1	1	1
Post Closure	N/A	13d	13d iii	148	H	Abandonment survey Undertake sampling of groundwater near the pad	High Ambition	Groundwater Sampling of monitoring boreholes and analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals	Quant	MM	Possible - high	1	-	1	1	1
Post Closure	N/A	13d	13d iv	149	-	Abandonment survey Obtain data on drinking water abstraction points (wells, boreholes, springs, surface water abstraction points	0	Drinking water abstraction points Obtain water quality data and water gas content from water abstraction points in the operational area (e.g. regarding dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals, isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals)	Quant	MM	Possible - high	1	-	1	1	1
Post Closure	N/A	13d	13d v	150	-	Abandonment survey Undertake land condition (soil) survey around pad	0	Land condition (soil) Establish land condition in immediate are of the pad and analyse for analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, asbestos, chloride	Quant	MM	Possible - high	1	-	1	1	1
Post Closure	N/A	13d	13d vi	151	-	Abandonment survey Undertake survey of biodiversity, ecology and invasive species survey	Assumed to be Middle Ambition	Scope will vary depending on presence of protected species and notable habitats and whether a designated site.	Quant	LL	No	1	-	1	-	1
Post Closure	N/A	13d	13d vii	152	-	Abandonment survey Undertake sampling for methane near surface in the pad location	0	0	Quant	MM	No	1	-	1	1	1
Post Closure	N/A	13d	13d viii	153	L	Abandonment survey Undertake assessment of landuse, infrastructure and buildings	LOW Undertake assessment of landuse, infrastructure and buildings through desk study	LOW AMBITION. Desk study and mapping of landuse, infrastructure and buildings. Objective is to enable comparison with baseline assessment and consequently any impacts.	Quant	LL	No	-	-	-	-	-
Post Closure	N/A	13d	13d viii	154	H	Abandonment survey Undertake assessment of landuse, infrastructure and buildings	HIGH Undertake assessment of landuse, infrastructure and buildings survey through desk study and aerial survey	HIGH AMBITION. As above plus remote (aerial) survey of land, land uses, structures etc. Objective is to enable comparison with baseline assessment and consequently any impacts.	Quant	MM	No	1	-	1	-	1
Post Closure	N/A	13d	13d ix	155	L	Abandonment survey Undertake assessment of ex-anti underground wells and structures	LOW Undertake assessment of underground wells and structures through desk study	LOW AMBITION. Check baseline list of penetrations into zone within area (from well history databases). Relates to wells and structures in place prior to UG activities.	Quant	LL	Possible - high	-	-	-	1	1
Post Closure	N/A	13d	13d ix	156	H	Abandonment survey Undertake assessment of ex-anti underground wells and structures	HIGH Undertake assessment of underground wells and structures desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells	HIGH AMBITION. As per LOW above plus: desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells. Relates to wells and structures in place prior to UG activities.	Quant	MM	No	-	-	-	-	-
Post Closure	N/A	12	12	157	-	Specific post closure risk assessment, well plugging, inspection and monitoring requirements (e.g. for releases to air, well integrity, periodicity of inspections, wellhead monitoring every 90 days)	0	Measure includes: Flush wells with a buffer fluid before plugging Plug wells. Use two cement plugs: one in producing formation and one for surface to bottom of drinking water level, fill the remainder with mud. Perform a mechanical integrity test prior to plugging to evaluate integrity of casing and	Quant	HH	Possible - high	1	1	1	1	1

Categorisation		Measure info										Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legislation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating			1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Post Closure	N/A	13b	13b i	158	-	Specific post closure well inspection, maintenance and monitoring/reporting programme (i) following detection of possible pollution (low ambition); (ii) periodic inspection and monitoring (high ambition)	Post closure well inspection, maintenance and monitoring/reporting programme - following detection of possible pollution (low ambition)	Following detection of possible pollution and after well closure. Well inspection, maintenance and monitoring to ensure integrity. Reports would be prepared and submitted to competent authority by operators. Duration will be until licence surrender. Programme would include: - mechanical integrity testing (MIT) - determination of any necessary maintenance - submission of reports - implementation of remedial actions as necessary	Qual	LH		Possible - high	-	-	-	1	1
Post Closure	N/A	13b	13b ii	159	-	Specific post closure well inspection, maintenance and monitoring/reporting programme (i) following detection of possible pollution (low ambition); (ii) periodic inspection and monitoring (high ambition)	Post closure well inspection, maintenance and monitoring/reporting programme - periodic inspection and monitoring (high ambition)	Well inspection, maintenance and monitoring to ensure integrity on a regular basis (e.g. 3 yearly). Reports would be prepared and submitted to competent authority by operators. Duration will be until licence surrender. Programme would include: - mechanical integrity testing (MIT) - determination of any necessary maintenance - submission of reports - implementation of remedial actions as necessary	Qual	MH		Possible - high	-	-	-	1	1
Post Closure	N/A	13c	13c	160	-	Ownership and liability of wells transferred to a competent authority on surrender of the site licence following a period of monitoring	0	Following a period of monitoring [minimum 20 years] after well/pad closure and subsequent site reinstatement, the site licence is surrendered and the ownership and liability of the wells is transferred to the appropriate competent authority in MSs. Following transfer, the competent authority takes on responsibility and liability for any resultant environmental damage linked to the	Qual	HH		No	-	-	-	1	1
Public Acceptance	N/A	N23	N23	161	-	Public disclosure by operators of environmental monitoring (baseline, operational and post closure), resource use (water use and chemicals), production, incidents (e.g. pollution events, well failure) and well integrity information	0	Operators would be required to publicly disclose baseline, ongoing monitoring and well integrity information through website establishment and maintenance and collation of information. Applies to baseline information through to transfer of responsibility to Competent Authority	Qual	LL		Possible - low	1	-	1	1	1
Public Acceptance	N/A	15	15i	162	L	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) for permitting	LOW AMBITION. Engagement at permitting (website, information, public meetings) and abandonment and relinquishing of permits. (website and information).	Note aspects of public acceptance linked to chemicals are on the chemicals tab. The focus here is on wider public engagement.	Quant	LL		Possible - high	1	1	1	1	1
Public Acceptance	N/A	N41	N41	163	-	Member State Competent Authorities provide information on the licences and permits of operators involved in unconventional gas exploration and production	0	0	Quant	LL		No	-	-	-	1	1
Public Acceptance	N/A	N42	N42	164	-	Prohibit non-disclosure agreements between local residents and/or landowners and unconventional gas operators	0	0	Qual	LL		No	-	-	-	1	1
Public Acceptance	N/A	N40	N40	165	-	Member State Competent Authorities provide a map of planned and existing exploration, production and abandoned well locations	0	Also relevant to underground potentially	Quant	MM		No	1	-	1	-	1
Public Acceptance	N/A	15	15i	166	H	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) for permitting	HIGH AMBITION. As per low ambition PLUS the following: Early stage consultation (initial exploration, pre-site development and pre-permitting) consultation (website, information preparation, public meetings). Production stage ongoing consultation (ongoing website and information provision)	Note aspects of public acceptance linked to chemicals are on the chemicals tab. The focus here is on wider public engagement.	Quant	MM		Possible - low	-	-	-	1	1
Public Acceptance	N/A	N03	N03	167	-	All permits/authorisations/licences relating to environmental risk management to be made available to the public and included on a central data repository for all unconventional gas operations in the Member State / EU	0	0	Qual	MM		No	1	-	1	1	1
Public Acceptance	N/A	N04	N04	168	-	EU institutions and/or Member States provide peer reviewed information to the public on a regular basis on the current state of knowledge of potential environmental risks and benefits from unconventional gas and available measures to manage those risks	0	0	Qual	MM		No	-	-	-	-	-
Other Measures	sea	N34	N34	169	-	Public authorities produce an underground regional impact assessment to optimise resource allocation between unconventional gas and other underground resources (e.g. geothermal energy)	0	0	Quant	LL		No	1	-	1	1	1
Other Measures	permit	N35	N35	170	-	Member States implement integrated permitting for unconventional gas	0	0	Qual	LL		No	-	1	1	1	1
Other Measures	N/A	N25	N25	171	-	Reversal of the burden of proof for unconventional gas operators in the context of liability in case of environmental damage	0	0	Qual	LL		No	-	-	-	-	-

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	**Sub**	**Measure ref.**		**Order**	**LOW vs. HIGH**	**Measure**	**Sub-measure description**	**Further definition**	**Quant/ qual**	**LoA rating**		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Other Measures	N/A	N38	N38	172	-	Maintain operator liability for any pollution arising from wells for a period of 100 years	0	0	Qual	LM	No	1	-	1	-	1
Other Measures	N/A	N39	N39	173	-	Maintain operator liability for any pollution arising from wells indefinitely	0	0	Qual	LM	No	1	-	1	-	1
Other Measures	operator	N28	N28	174	-	Assessment by the Competent Authority of the technical and financial capacity of an operator	0	0	Qual	LM	No	-	-	-	1	1
Other Measures	trans	59a	59a	175	-	Traffic impact assessment including consideration of noise, emissions and other relevant impacts	0	0	Quant	LM	Possible - high	1	-	1	1	1
Other Measures	operator	N29	N29	176	-	Financial guarantees by operators for environmental and civil liability covering any accidents or unintended negative impacts caused by their own activities or those outsourced to others (to cover incidents and accidents during and after operations, restoration of site)	0	0	Qual	LM	No	-	-	-	1	1
Other Measures	efficiency	N36	N36	177	-	Operators work together to ensure efficient provision of gas collection and wastewater treatment infrastructure	0	0	Qual	LM	No	-	-	-	-	-
Other Measures	ecology	N21	N21	178	-	Implement precautions to prevent invasive species by cleaning vehicles	0	0	Qual	ML	No	-	-	-	-	-
Other Measures	permit	N15	N15	179	-	Mandatory EIA for all projects expected to involve hydraulic fracturing, before exploration starts	0	0	Quant	ML	No	1	1	1	-	1
Other Measures	permit	N16	N16 i	180	-	Mandatory EIA (i) after initial phase of well exploration and before first test fracturing, and (ii) before production commences	Mandatory EIA according to Directive 2011/92/EU after well exploration and before first test fracturing	0	Quant	ML	No	-	-	-	1	1
Other Measures	permit	N16	N16 ii	181	-	Mandatory EIA (i) after initial phase of well exploration and before first test fracturing, and (ii) before production commences	Mandatory EIA according to Directive 2011/92/EU before production commences	0	Quant	ML	No	-	-	-	1	1
Other Measures	permit	N17	N17	182	-	Assessment of whether full project is likely to have significant effects on the environment during prospecting phase (i.e. extending the existing requirement in relation to deep drillings under the EIA Directive to include screening prior to development of exploration plans/prospecting and taking account of the entire project)	0	0	Quant	ML	No	-	-	-	-	-
Other Measures	incident	N08	N08a	183	-	In the case of an incident/accident significantly affecting the environment: (a) operator informs competent authority immediately; (b) competent authority provides details of the circumstances of the incident and effects on the environment to a designated body at EU level who will make non-confidential information available to the public	In the case of an incident/accident significantly affecting the environment, operator to inform competent authority immediately.	0	Qual	ML	Possible - high	-	-	-	1	1
Other Measures	incident	N08	N08b	184	-	In the case of an incident/accident significantly affecting the environment: (a) operator informs competent authority immediately; (b) competent authority provides details of the circumstances of the incident and effects on the environment to a designated body at EU level who will make non-confidential information available to the public	In the case of an incident/accident significantly affecting the environment, competent authority to provide details of the circumstances of the incident and effects on the environment to a designated body at EU level who will make non-confidential information available to the public	0	Qual	ML	No	-	-	-	-	-
Other Measures	trans	59b	59b	185	-	Transport management plan (including consideration of available road, rail, waterway infrastructure)	0	0	Quant	MM	Possible - high	1	-	1	-	1
Other Measures	trans	60c	60c	186	-	Site selection close to water sources to minimise haulage requirements	0	0	Qual	MM	No	-	-	-	-	-
Other Measures	trans	61b	61b i	187	-	Minimise resources demands and hence traffic movements through (i) water management plans and (ii) wastewater management plans	i) water management plans to minimise water demands and hence traffic movements.	0	Qual	MM	No	1	-	1	1	1
Other Measures	trans	61b	61b ii	188	-	Minimise resources demands and hence traffic movements through (i) water management plans and (ii) wastewater management plans	ii) wastewater management plans to minimise water demands and hence traffic movements.	0	Qual	MM	No	1	-	1	1	1
Other Measures	trans	61c	61c	189	-	Site selection close to wastewater treatment / disposal facilities to minimise haulage requirements	0	0	Qual	MM	No	-	-	-	-	-
Other Measures	incident	N09	N09	190	-	Operator to develop and maintain a contingency plan to address foreseeable impacts of operating conditions on environmental risk management (e.g. degradation of well barriers, casing/cementing as per measure 22)	0	0	Quant	MM	Possible - low	1	-	1	1	1
Other Measures	noi	51a	51a	191	-	Maximum noise levels specified	0	0	Qual	MM	Possible - high	-	-	-	-	-
Other Measures	noi	51c	51c	192	-	Noise screening installation: (i) screen drilling and fracturing rigs with noise barrier / enclosure; (ii) acoustic fencing around the site perimeter.	0	Screen drilling and fracturing rigs with noise barrier/enclosure. Acoustic fencing around the site perimeter	Quant	MM	Possible - high	1	-	1	-	1
Other Measures	noi	51d	51d	193	-	Operational hours specified	0	(Noise abatement)	Qual	MM	Possible - low	1	-	1	-	1
Other Measures	noi	51e	51e	194	-	Vehicle routes specified	0	(Noise abatement)	Qual	MM	Possible - high	1	-	1	-	1
Other Measures	noi	51f	51f	195	-	Machinery orientation and selection to minimise noise	0	(Noise abatement)	Qual	MM	Possible - low	1	-	1	-	1
Other Measures	noi	3a	3a viii	196	-	Site baseline Undertake noise study	0	Consult with relevant regulatory authority and carry out baseline noise monitoring	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	noi	3b	3b viii	197	-	Monitoring Undertake monitoring of noise	0	0	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	monitor	N27	N27	198	-	Member States carry out strategic monitoring of unconventional gas activities at the level of the gas play to assess overall impacts and reaction as necessary	0	0	Quant	MM	No	1	-	1	1	1
Other Measures	guidance	N30	N30	199	-	The European Commission to develop further criteria/guidance for the assessment of environmental impacts from unconventional gas	0	0	Quant	MM	No	-	-	-	-	-
Other Measures	inspection	N31	N31	200	-	Inspections by Competent Authorities during all stages of development (e.g. of well completion reports and environmental risk management and controls)	0	0	Quant	MM	Possible - high	1	-	1	1	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1; Option B Amendment to the Acquis plus Guidance = 3; Option C Dedicated Legislation (Directive) plus Guidance = 5; Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Other Measures	skills	N32	N32	201	-	Competent Authorities have available sufficient inspection capacity and appropriately skilled inspectors	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	inspection	N33	N33	202	-	Independent inspection during all stages of development of well integrity	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	ecology	N37	N37	203	-	Pad construction activities staged to reduce soil erosion and to coincide with low rainfall periods	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	baseline	3a	3a iv	204	-	Site baseline Obtain data on drinking water abstraction points (wells, boreholes and springs)	0	Develop list of wells, boreholes, springs, surface water abstraction points within area (from public data). List names and depth of all potentially affected (by UG) underground sources of drinking water Provide geochemical information and maps/cross section on subsurface aquifers. Obtain water quality data and water gas content from existing available data.	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	monitor	3a	3a v	205	-	Site baseline Undertake land condition (soil) survey around pad	0	Trial pits and analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, asbestos, chloride.	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	trans	3a	3a vii	206	L	Site baseline Undertake transport and traffic study.	LOW AMBITION Undertake transport and traffic study. Liaise with highway authority and identify relevant routes to/from well pad.	0	Quant	MM	Possible - high	1	-	1	-	1
Other Measures	trans	3a	3a vii	207	H	Site baseline Undertake transport and traffic study.	HIGH AMBITION Undertake transport and traffic study. As per LOW plus traffic survey and traffic modelling	0	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	ecology	3a	3a ix	208	-	Site baseline Undertake survey of biodiversity and ecology survey	Assumed to be Middle Ambition	Scope will vary depending on presence of protected species and notable habitats and whether a designated site.	Quant	MM	Possible - low	1	-	1	1	1
Other Measures	baseline	3a	3a xii	209	L	Site baseline Undertake assessment of landuse, infrastructure and buildings	LOW AMBITION. Undertake assessment of landuse, infrastructure and buildings through desk study	Desk study	Quant	MM	Possible - high	1	-	1	-	1
Other Measures	baseline	3a	3a xii	210	H	Site baseline Undertake assessment of landuse, infrastructure and buildings	HIGH AMBITION. As LOW plus remote (aerial) survey of land, land uses, structures etc.	0	Quant	MM	No	1	-	1	-	1
Other Measures	monitor	3b	3b iv	211	-	Monitoring Undertake monitoring of drinking water abstraction points (wells, boreholes, springs, surface water)	0	Obtain water quality data and water gas content from existing available data. Ongoing monitoring. Annual desk study using data from abstraction points	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	monitor	3b	3b v	212	-	Monitoring Undertake land condition (soil) tests every five years outside site boundary	0	Analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, chloride).	Quant	MM	No	1	-	1	-	1
Other Measures	trans	3b	3b vii	213	-	Monitoring Undertake monitoring of traffic numbers and patterns	0	Traffic count site/system to provide weekly or monthly counts.	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	monitor	3b	3b xi	214	-	Monitoring Undertake monitoring of energy source and use	0	0	Quant	MM	No	1	-	1	-	1
Other Measures	monitor	3b	3b xii	215	-	Monitoring Undertake monitoring of greenhouse gas emissions	0	0	Quant	MM	No	-	-	-	1	1
Other Measures	ecology	3b	3b xvi	216	-	Monitoring Undertake periodic surveys of biodiversity, ecology and invasive species	Assumed to be Middle Ambition	Scope and frequency will vary depending on presence of protected species and notable habitats and whether a designated site. Invasive species mitigation plan if required.	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	incident	3b	3b xix	217	-	Monitoring Undertake monitoring of spills volume, nature, location and clean-up (including reporting)	0	0	Quant	MM	Possible - high	1	-	1	1	1
Other Measures	cumulative	7	7	218	-	Cumulative effects (e.g. air pollution, traffic impacts, water resource requirements) of gas play development assessed in planning and permitting taking into account other (non-unconventional gas) developments and plans.	0	Complimentary with other measures associated with planning. Linked to SEA	Qual	MM	No	-	-	-	1	1
Other Measures	permit	N02	N02	219	-	Operator, as part of permit conditions, obtains independent evaluation of environmental risk management measures for gas concession before fracturing commences and at regular intervals thereafter	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	permit	N06	N06	220	-	Operations to be subject to an integrated permit from the national authority, setting measures to manage environmental impacts for all environmental media (air surface/ground water, land). Combined monitoring and inspection regimes where separate competent authorities exist	0	0	Quant	MM	No	1	1	1	1	1
Other Measures	sea	N13	N13	221	-	Member States carry out SEA to set up plans/programmes setting the framework for unconventional gas projects before granting concessions for unconventional gas exploration and production and assess environmental effects of such plans. Assessment to address surface aspects such as water abstraction, waste treatment and disposal, transport, air quality, landtake, species diversity as well as known underground risks. Assessment to be reviewed before production commences on the basis of information obtained during the exploration phase. Those MS that have already granted concessions to perform	0	0	Quant	MM	No	-	-	-	1	1
Other Measures	equip	N18	N18	222	-	Ensure equipment is compatible with composition of fracturing chemicals	0	0	Qual	MM	Possible - high	1	-	1	-	1

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options: Option A Guidance = 1 Option B Amendment to the Acquis plus Guidance = 3 Option C Dedicated Legislation (Directive) plus Guidance = 5 Option D Dedicated Legisalation (Regulation) plus Guidance = 5				
Main	Sub	Measure ref.		Order	LOW vs. HIGH	Measure	Sub-measure description	Further definition	Quant/ qual	LoA rating		1. Guidance	2. Amendment	3. Amendment + Guidance	4. Legislation	5. Legislation + Guidance
Other Measures	equip	N19	N19	223	-	Carry out thorough planning and testing of equipment prior to hydraulic fracturing operations	0	0	Qual	MM	Possible - high	1	-	1	-	1
Other Measures	management	N20	N20	224	-	Environmental management system accreditation for unconventional gas installation operators	0	0	Quant	MM	No	1	-	1	-	1
Other Measures	materials	30e	30e	225	-	Muds restricted to approved list with known properties/safety data or non-toxic drilling muds	Restrict muds to approved list	Specify the use of muds from an approved list to minimise the risk of harmful (polluting) mud production which could result in polluting spills	Qual	MH	No	-	-	-	-	-
Other Measures	materials	30e	30e	226	-	Muds restricted to approved list with known properties/safety data or non-toxic drilling muds	Restrict muds to non-toxic drilling muds	Specify the use of water-based muds/non-toxic chemical additives	Qual	HH	No	1	1	1	-	1
Other Measures	management	29e	29e	227	-	Site reinstatement plan	0	Purpose of measure is to develop a reinstatement plan for the site following well closure and abandonment.	Quant	MH	Yes	1	-	1	1	1
Other Measures	incident	9b	9b	228	-	Emergency response plan developed and put in place covering: - leaks from the well to groundwater or surface water - releases of flammable gases from the well or pipelines - fires and floods - leaks and spillage of chemicals, flowback or produced water - releases during transportation	0	0	Qual	HM	Yes	-	1	1	1	1
Other Measures	incident	9a	9a	229	-	Consideration of major hazards for all stages in the life cycle of the development (early design, through operations to post abandonment) and development of HSE case or similar demonstrating adequacy of the design, operations and HSE management (including emergency response) for both safety and environmental major impacts	0	0	Qual	HH	Possible - high	1	1	1	1	1
Other Measures	trans	60a	60a	230	-	Use of temporary surface pipes for distribution of water supply	0	Temporary pipes laid above ground to supply water to pads.	Qual	HH	No	-	-	-	-	-
Other Measures	trans	60b	60b	231	-	Use of temporary surface pipes for collection of flowback	0	Temporary pipes laid above ground to collect flowback and transport to treatment plant.	Qual	HH	No	-	-	-	-	-
Other Measures	trans	61a	61a	232	-	Use of temporary surface pipes for collection of produced water	0	Temporary pipes laid above ground to collect produced water and transport to treatment plant.	Qual	HH	No	1	1	1	-	1

HOW TO OBTAIN EU PUBLICATIONS

Free publications:

- one copy:
  via EU Bookshop (http://bookshop.europa.eu);

- more than one copy or posters/maps:
  from the European Union's representations (http://ec.europa.eu/represent_en.htm);
  from the delegations in non-EU countries
  (http://eeas.europa.eu/delegations/index_en.htm);
  by contacting the Europe Direct service (http://europa.eu/europedirect/index_en.htm)
  or calling 00 800 6 7 8 9 10 11 (freephone number from anywhere in the EU) (*).

  (*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

Priced publications:

- via EU Bookshop (http://bookshop.europa.eu).

Priced subscriptions:

- via one of the sales agents of the Publications Office of the European Union
  (http://publications.europa.eu/others/agents/index_en.htm).

KH-01-16-390-EN-N

doi:10.2779/001875