European Commission

Technical support for assessing the need for a risk management framework for unconventional gas extraction

Final report

amec

PHILIPPE & PARTNERS
avocats - advocaten - law firm

Institute for European Environmental Policy

European Commission DG Environment

Technical Support for Assessing the Need for a Risk Management Framework for Unconventional Gas Extraction

Final Report



AMEC Environment & Infrastructure UK Limited

August 2014

Copyright

Third-Party Disclaimer

Document Revisions

No.	Details	Date
01	Draft	8 May 2013
02	Final	3 June 2013
03	Final	5 July 2013
04	Final	15 July 2013
05	Final	23 January 2014
06	Final	24 February 2014
07	Final	22 July 2014
08	Final	5 August 2014

amec

Report for

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

European Commission DG Environment

Technical Support for Assessing the Need for a Risk Management Framework for Unconventional Gas Extraction

Final Report

AMEC Environment & Infrastructure UK Limited

August 2014

Main Contributors

Caspar Corden (AMEC)
Andrew Farmer (IEEP)
Jin Lee (AMEC)
Daren Luscombe (AMEC)
David Tyrer (AMEC)

Wider Contributors

Abby Bazin (AMEC)
Ben Fretwell (AMEC)
Tony Marsland (AMEC)
Robert McGregor (AMEC)
Cécile Musialski (Philppe & Partners)

Issued by

....
Daren Luscombe

Approved by

....
Caspar Corden

AMEC Environment & Infrastructure UK Limited

155 Aztec West, Park Avenue, Almondsbury,
Bristol BS32 4UB, United Kingdom
Tel +44 (0) 1454 822 000
Fax +44 (0) 1454 822 010

Doc Reg No. 32834rr014i7

r:\projects\32834 ec shale gas risk management framework\d design\05 impact assessment\report\final august 2014\32834 report 20140805.doc

Executive Summary

Purpose of this Report

This is the Final Report for a project on ‘Technical Support for Assessing the Need for a Risk Management Framework for Unconventional Gas Extraction’, contract 070307/2012/630420/SER/ENV.F.1. The report presents an overview of the issues associated with unconventional gas extraction that uses high volume hydraulic fracturing and horizontal drilling (such as shale gas) from an environmental and regulatory perspective; an assessment of measures available to address environmental risks and their impacts; and a description of selected policy options available to implement such measures.

The report is intended to be one of a number of sources used by the Commission as ‘building blocks’ for an impact assessment accompanying a possible proposal for an European Union (EU) risk management framework for unconventional gas. The focus of this report is on the impacts (costs and benefits) of technical and operational measures to address environmental risks and the merits of different potential policy options defined by the Commission.

Context

Extraction of unconventional gas using high volume hydraulic fracturing combined with horizontal drilling (such as shale gas) is in its infancy in the EU but has the potential to become more widespread. It is acknowledged that there are uncertainties and inadequacies regarding the scope of current policy, legislation, knowledge and management practices governing the extraction of unconventional gas in the EU. This is resulting in a variety of policy responses by Member States. A patchwork of national policies could create difficulties for businesses operating across borders and cause distortions in competition within the EU and may also not guarantee appropriate management of environmental impacts and risks, some of which have a cross-border dimension (e.g. water and air pollution).

While there are similarities with conventional hydrocarbons extraction, there are also important differences, which are principally that unconventional gas:

- Makes much more extensive use of hydraulic fracturing and of horizontal drilling;
- Uses a larger volume of water and chemical additives for hydraulic fracturing, which in turn generates larger volumes of wastewater (flowback) that requires treatment and disposal;
- Has the potential to create induced seismic events and to disturb geological conditions as a result of hydraulic fracturing of rocks;

- Requires a larger number of production wells, with multiple wells drilled from one well pad and numerous pads across an area. As the risks are related mainly to the drilling and hydraulic fracturing operations, an increased number of wells increases the likelihood of environmental damage occurring;
- The transportation of water, chemicals, proppant and other items to the well pad and the transport of flowback, produced water and drilling fluids, from the pad have proven to be significant issues (e.g. in North America) presenting air quality (emissions and dust), noise and traffic impacts; and
- Wells are short-lived relative to those used for conventional gas extraction.

There is, in addition, greater public concern and public scrutiny of unconventional gas when compared to conventional oil and gas, due to the negative publicity generated by unconventional gas production, primarily in North America.

Objectives, Scope, Limitations and Project Process

Objectives

The objective of this study was to provide support for the development of possible Commission initiatives on managing potential impacts and risks associated with unconventional gas extraction in Europe. To this end, the project has:

- Identified and assessed relevant measures, at the EU level, for preventing or managing the risks from unconventional gas developments;
- Prepared extended support for an impact assessment on the need and possible options for an EU risk management framework for unconventional gas; and
- Provided other support for developing possible measures and elements of a risk management framework.

Scope and Boundary of the Study

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

- Regulatory and technical analysis:
  - Summarise key risks and hazards, building on work conducted by AEA[1] for DG Environment;
  - Identify suitable measures to manage such risks.
- Support the development of policy options, in discussion with the Commission, to manage risks;

1 'Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe', AEA 2012, report for European Commission, DG Environment

- Impact assessment: provide ‘building blocks’ supporting an Impact Assessment of the selected policy options in line with the Commission’s Impact Assessment Guidelines; and

- Support for the development of a risk management framework: as required, provide technical or legal support to the development of a defined risk management framework.

This study has the following limitations:

- The focus of the study is unconventional gas exploration and production that uses high volume hydraulic fracturing and horizontal drilling (such as shale gas), referred to as ‘unconventional gas’ in this report. Other unconventional fossil fuels (such as tight gas, tight oil and coal bed methane) are not within the scope of the study;

- It should be borne in mind that there are currently few active unconventional gas projects involving the use of high volume hydraulic fracturing combined with horizontal drilling (such as shale gas) in the EU so current work has had to take into account expected future developments;

- A number of technical (and other) measures to address the potential environmental risks were identified. In the event of significant future unconventional gas development in the EU, many of these measures could be adopted without the need for any additional action at EU level. However, given uncertainty about what the future developments will look like, the application of these risk reduction measures cannot be assured, and in this study it has been assumed that measures will not necessarily be implemented if there is no EU-level requirement to do so. It is recognised that this approach tends to overestimate the likely compliance requirements and costs and thus measures that industry may adopt as normal practice are also considered in the analysis;

- Some of the technical measures that were assessed were straightforward to characterise and assign costs to (e.g. specific engineering-related controls on well design and maintenance). However, others were subject to much more uncertainty, related for example, to how the industry develops in the EU, taking into account local geographical and other conditions. There are therefore a number of limitations and uncertainties associated with some of the data presented here; and

- 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.

Project Process

The project proceeded in a stepwise process entailing the identification of risks, the identification of measures that could mitigate the risks and review of the application of the *acquis communautaire* to establish whether or not those measures are already required by the current EU legal framework. This was followed by identification of measures that were considered non-business as usual (i.e. not required through application of the *acquis*) and an evaluation of associated costs and benefits (either qualitatively or quantitatively). Measures were then categorised by theme (see below). Policy options were first considered in broad terms. Combinations of measures were then selected by the Commission for detailed assessment of four specific policy options.

The 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.

The Current State of Play and the Need for Further Action

Examination of the EU environmental *acquis communautaire* and emerging best practice/voluntary approaches indicates that, whilst many of the risks posed by unconventional gas extraction at the surface are likely to be addressed, a coherent and comprehensive approach is absent, in particular with regard to strategic planning, environmental impact assessment, baseline monitoring and reporting requirements, capture of gases, well integrity, and public disclosure of chemicals used. There are issues regarding the clarity and effectiveness of the current EU legislative framework, notably with reference to mining waste, environmental impact assessment and air and water protection that could result in uncertainty for the Member States, or provide a basis for divergent interpretation of legislation. Furthermore, there are gaps in the *acquis* in particular with regard to underground risks. Emerging best practice and voluntary approaches attempt to address these gaps but do not *guarantee* that the proposed approaches will be adopted either in part or in full by all operators.

With regard to national level regulation, the development of regulation at a Member State level runs the risk of a lack of a level playing field for business. Moreover, a number of unconventional gas plays extend across national borders as can environmental effects. This presents a strong argument for action at EU level to avoid or mitigate these impacts and risks.

A further point arising from developments at a Member State level is one of timing. Due to the current development of the sector, Member States are reacting now with various regulatory or non-regulatory responses. It is, therefore, important for there to be an early response at an EU level so as to support Member States in addressing the challenges raised by these activities.

Measures to Address Risks and their Impacts

Measure Categorisation

The project lifecycle and wide range of risks presented by unconventional gas has resulted in over 200 non-business as usual (BAU) measures being identified. The measures were categorised into themes[2]. Section 3 of this report presents descriptions of the available measures that may be applied to address risks, together with their impacts. The measures were categorised to identify BAU or non-BAU measures (BAU measures being those which are required by the *acquis*), the project stage(s) that measures would be applied to and the 'level of ambition' of measures to reduce likelihood of the risks and the level of reduction of damage and/or consequences.

[2] Zoning; Underground risks; Chemicals; Water depletion; Surface water quality; Air quality; Waste; Post closure; Public acceptance; and Other measures (a wide range of aspects including incident response, assurance and delivery, noise management and mitigation, environmental permitting and assessment and transportation measures).

It was acknowledged, that many non-BAU measures might be adopted under normal practice by the industry (for example, measures to maintain well safety). That certain non-BAU measures might be adopted by operators regardless of EU legislation (e.g. due to standard industry practice, or to minimise financial risk of investments) was an important consideration. 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 such measures by operators was then considered and (assumed, illustrative) uptake rates integrated into the analysis. This enabled the existing costs of those non-BAU measures that were likely to be applied by industry as a result of current practices to be taken into account.

Illustrative Concession

An 'illustrative concession' approach was used to describe the potential environmental, economic and social impacts, in order to ensure consistency of assumptions in developing and evaluating measures. The illustrative concession was 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, vehicles movements, etc. The illustrative concession approach was also considered to be appropriate given the uncertainties around the likely future development of unconventional gas under the status quo.

The use of the illustrative concession approach takes into account likely variability in scale of operations according to different geographic regions, amongst other factors determining scale. Furthermore, geographical considerations have been taken into account through a combination of specific measures addressing particular types of geographical locations/zones.

Policy Options to Deliver Measures

A number of policy options could be used to address the gaps identified for the control of unconventional gas facilities, such as:

- Do nothing (i.e. the baseline);
- Best practices and voluntary approaches by the industry;
- A recommendation and EU guidance to clarify the interpretation of certain pieces of EU legislation;
- Amendments of individual pieces of EU legislation;
- Dedicated instrument in the form of a directive to manage identified risks;
- Dedicated instrument in the form of a regulation to manage identified risks[3]; and

[3] In this analysis, both a directive and a regulation are referred to as options for delivery of a risk management framework. Within this report, a dedicated 'directive' should be read as being an instrument setting general principles (or 'goal-setting'

- A combination of various options.

The preferred policy options selected by the Commission to examine in detail were as follows:

- 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.[4]

Policy Option Costs

The following table presents the annualised compliance costs for different policy options.

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**
Operators	*0 to 1,512,000*	*1,512,000*	*1,578,000*	*1,674,000*
Authorities	*0 to 2,000*	*2,000*	*12,000*	*12,000*

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 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.

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 3.1.2) some of the measures are likely to be normal practice by operators and assumed existing uptake rates were applied (for illustrative purposes). To avoid overestimating the annualised compliance costs of policy options in case these measures would be implemented in

legislation). A 'regulation' in the context of the current report would include specific detailed obligations. In practice, such specific detailed obligations could also be included in a (more prescriptive) directive, rather than a regulation.

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

practice, costs of these measures were adjusted. Annual compliance costs of policy options, taking account of illustrative uptake rates are presented in the table below.

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

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 667,000	667,000	729,000	825,000
Operators	*0 to 666,000*	*666,000*	*718,000*	*814,000*
Authorities	*0 to 1,000*	*1,000*	*10,000*	*10,000*
Difference compared to pre-adjustment	*Up to 44%*	*44%*	*46%*	*49%*
Total annualised compliance costs , with adjustment for non-BAU measures *likely to be applied and possible to be applied* in practice	0 to 596,000	596,000	654,000	737,000
Operators	*0 to 595,000*	*595,000*	*643,000*	*727,000*
Authorities	*0 to 1,000*	*1,000*	*10,000*	*10,000*
Difference compared to pre-adjustment	*Up to 39%*	*39%*	*41%*	*44%*

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.

Conclusions

Key Environmental Risks of Unconventional Gas

The principal risks presented that are specific to unconventional gas exploration and production can be summarised, by theme as follows:

- Underground contamination and seismicity aspects: particularly risks from well failure, introduction of pollutants due to induced fractures providing pathways to groundwater resources through either pre-existing man-made or natural structures, induced seismicity and the potential impact on well integrity, creation of geological pathways for pollutants and possible minor earth tremors;

- Chemicals usage: risks resulting from potentially inappropriate selection of chemicals in hydraulic fracturing and/or unsuitable assessment leading to unacceptable risks to the environment from releases; lack of public/regulator scrutiny on specific chemicals used leading to unsuitable control of risks;

- Water depletion: extraction of groundwater or surface water for use in fracturing and the resulting risk of quality and quantity impacts on water resources;

- Surface water quality: the risk of pollution incidents stemming from spillage of wastewaters, muds or chemicals;

- Air quality: risks resulting from emissions from diesel engines providing power onsite, air pollutants released from the well, flowback or produced water (fugitive and/or flared and/or vented) and emissions from vehicles associated with haulage;

- Waste: risks resulting from flowback or produced water leading to pollution of surface water, due to lack of proper characterisation or treatment plant not being suitable to treat contaminants;

- Zoning and landtake: zoning i.e. risks resulting from well-pads located at unsuitable distances from aquifers, drinking water sources, residential areas, nature protection areas, etc. and landtake requirements (leading to a range of other environmental impacts/risks, with cumulative impacts potentially being significant); and

- Traffic: risks from the large numbers of vehicle movements associated with water supply and flowback and produced water transportation for treatment.

Problem Characterisation

Issues relevant to EU environmental law with regard to unconventional gas have been identified. These include:

- Although there are relevant requirements across the *acquis*, these are not in sufficient detail or specific enough to address all risks arising from unconventional gas exploration and production using the measures identified here;

- Permits under the Mining Waste Directive are limited in their capacity to address all aspects of unconventional gas operations, as they focus on waste management; and

- The *acquis* does not fully address the underground environment, geological, hydrogeological and induced seismicity aspects of unconventional gas extraction.

At the Member State level[5]:

- There are legal uncertainties. For example, regulation may be primarily focussed on water, industrial and/or mining waste law (or a combination, requiring operators to have several permits). As a result requirements at national level are not only different, but sometimes contradictory;
- None of the Member States examined have a regulatory regime specifically for unconventional gas;
- An analysis of selected Member States has found that there is divergence in the regulation of unconventional gas extraction in Member States and also divergence in the interpretation of EU environmental law to address the challenges this type of facility places on regulators; and
- Regulatory uncertainties and gaps are prompting Member States to review legislation and draft new law. Divergence may continue and not all regulatory development at Member State level may deliver the necessary and required management of environmental impacts and risks, notably in the light of possible cross-border effects. Also developments at Member State level run the risk of providing a fragmented regulatory framework across the EU which could result in an uneven ‘playing field’ for business and increased business costs as individual companies adapt to different regulatory regimes.

Regarding best practice/voluntary actions by industry:

- Whilst best/recommended practice and voluntary approaches are emerging, they are not well established or fully integrated, particularly taking into account the early stage in development of certain unconventional gas resources such as shale gas in Europe. The industry across Europe may be aware of best practices but there remains no coherent industry approach or agreement to implement a recognised set of objectives or practices.

Regarding the need for action:

- Best practices may be able to address many of the main environmental risks presented by unconventional gas exploration and production but would need to be systematically applied by industry;
- A coherent and comprehensive approach is absent at EU level, in particular with regard to strategic planning, environmental impact assessment, integrated baseline reporting and monitoring requirements, capture of gases, well integrity, and public disclosure of chemicals used in each well;
- There are gaps in the *acquis* in particular with regard to underground risks;
- The development of regulation at the Member State level runs the risk of a lack of a level playing field for business; and

[5] Based on the conclusions of the report ‘Regulatory provisions governing key aspects of unconventional gas extraction in selected Member States’ (Milieu, 1st July 2013) for the European Commission.

- A response at EU level would help to address the cross-border dimension of unconventional gas and its environmental effects.

Measures to Address Risks

Over 200 potential non-BAU measures were identified. All of the measures were identified as addressing (partially or fully) specific identified environmental risks. Some of the measures could be applied in combination whilst others are alternatives, particularly where a different level of ambition of risk management is required.

Policy Options to Deliver Measures

It is not the purpose of this project to propose a particular option. However, it is clear that the current state of play (baseline option) would not ensure that all risks are addressed and would leave a fragmented regulatory landscape across the EU. The other options considered could all address the risks from unconventional gas to different extents. Legal amendment of existing legislation for example, could fully address some risks but not all, while voluntary approaches and guidance/recommendations can encompass all risks, but cannot guarantee practical application on the ground. A dedicated instrument would, however, be able to achieve this.

For the policy options selected for detailed analysis (see above), the pros and cons of each option can be summarised as follows:

- All of the options can take forward a large number of measures, but legislative change is necessary to deliver some critical measures and Option C and D would be able to deliver more measures than Option B;

- Option D sets measures in a different regulatory context to option C (their uptake is more likely because the policy option includes specific detailed obligations);

- Option A can be adopted faster relative to other options and can theoretically take forward a number of measures. Yet its non-binding character means that there is no guarantee that these will be implemented. Option A cannot, therefore, guarantee that the necessary environmental and health protection is delivered;

- Option A furthermore cannot guarantee that a level playing field is developed across the EU for unconventional gas exploration and production;

- Option B would take many years to be fully implemented due to the piecemeal approach, presenting major problems for legislators, regulators and operators both to ensure full delivery of the necessary amendments and uncertainties as the regulatory environment is subject to repeated changes. In contrast, Option C or D could be fully adopted in a shorter timetable;

- Options B, C and D retain benefits from guidance and sharing best practice where these would be effective instruments;

- There is an urgency to address issues of risk management of unconventional gas exploration and production and only Option A, C and D can be taken forward within a timetable that can address these needs; and

- Where Option B is attractive in providing necessary amendments to existing law, such amendments can be introduced within Option C and D, and for some Directives, would be implemented at a much earlier date than Option B.

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:[6]

  - Option A. Recommendation plus Guidance: €0 to €1,512,000;
  - Option B. Amendment to the *Acquis* plus Guidance: €1,512,000;
  - Option C. Dedicated Legislation (a directive) plus Guidance: €1,578,000; and
  - Option D. Dedicated Legislation (a regulation) plus Guidance: €1,674,000.

  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 of Options by up to 60% 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:[7]

  - Option A. Recommendation plus Guidance: €0 to €595,000;
  - Option B. Amendment to the *Acquis* plus Guidance: €595,000;
  - Option C. Dedicated Legislation (a directive) plus Guidance: €643,000; and
  - Option D. Dedicated Legislation (a regulation) plus Guidance: €727,000.

[6] Please refer to notes in the table above, 'Annualised Compliance Costs for Policy Options' regarding notes on option cost ranges.

[7] Please refer to notes in the table above 'Annualised Compliance Costs for Policy Options, with Adjustments for Non-BAU Measures that are likely to be Applied in Practice, and Difference to Annualised Compliance costs with No Adjustments' regarding notes on option cost ranges.

It should be noted that it was not possible to quantify some important and potentially costly measures (e.g. implementation of remedial measures if a well failure occurs) thus overall costs could be higher.

- Regarding administrative costs for Option C, for a single pad, total start-up costs associated with administrative costs of a risk management framework for exploration and production would be around €23,000 for an operator and €11,000 for the authorities. Annual recurring costs for monitoring, reporting and compliance checking would be around €6,000 for operators and €1,600 for the authorities for each well pad. Administrative costs for Option D are likely to be similar.

  An unconventional gas concession would have many pads (the illustrative concession assumes 250 pads per concession) and these would progressively be taken forward over many years so there would be efficiencies in permit development drawing on data from earlier site applications and operation;

  The estimated administrative cost associated with a permitting regime through a dedicated instrument would not be net cost as it would replace/combine elements of existing permits; and

- Administrative costs associated with amendments to the *acquis* would not remove the requirement for an operator to obtain several permits under the existing regulatory framework, hence Option B would not address these administrative burdens as effectively as Option C and D.

Contents

1. Introduction

1.1 Purpose of this Report

This is the Final Report for a project on 'Technical Support for Assessing the Need for a Risk Management Framework for Unconventional Gas Extraction', contract 070307/2012/630420/SER/ENV.F.1. The report presents an overview of the issues associated with unconventional gas extraction that uses high volume hydraulic fracturing and horizontal drilling (such as shale gas) from an environmental and regulatory perspective; an assessment of measures available to address environmental risks and their impacts; and a description of selected policy options available to implement such measures. The report provides one of the information sources that the Commission will use in developing a possible risk management framework for unconventional gas.

1.2 Project Context and Objectives

1.2.1 Context

Extraction of unconventional gas using high volume hydraulic fracturing combined with horizontal drilling (such as shale gas) is in its infancy in the European Union (EU) but has the potential to become more widespread. There are potential environmental hazards and risks that require understanding and appropriate management. It is acknowledged that there are uncertainties regarding the efficacy of current policy, legislation, knowledge and management practices governing the extraction of unconventional gas in the EU. It is recognised that the existing legislative framework may be inadequate to manage all risks effectively and that exploration and production practices are emerging[8].

There is, then, an emerging landscape of policy, regulation and operational practice but there are uncertainties regarding the coherence of this landscape. These uncertainties are resulting in a variety of policy responses by Member States (e.g. banning vs. encouraging extraction) and regulation of exploration and also public anxiety regarding new technologies and developments. A patchwork of national policies could create difficulties for businesses operating across borders and cause distortions in competition within the EU. It may also not guarantee appropriate management of environmental impacts and risks, some of which have a cross-border dimension (e.g. water and air pollution).

There is a need to establish a better understanding of the landscape, evaluate practices and approaches to risk management (both for exploratory projects and full scale production), establish options for managing this process and foster a level playing field across the EU. Alongside this project, the Commission also commissioned a project to carry out a review of the existing health and environmental regulatory provisions applicable at national level to unconventional fossil fuels such as shale gas in a selection of Member States and a project regarding the macro-

[8] See 'Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe' AEA 2012. Report for the European Commission, DG Environment.

economic effects of shale gas extraction in the EU. These all build upon and complement other studies undertaken for DG Environment in 2012.

While there are similarities with conventional hydrocarbons extraction, there are also important differences, which are principally that unconventional gas:

- Makes much more extensive use of hydraulic fracturing and of horizontal drilling;
- Uses a larger volume of water and of chemical additives for hydraulic fracturing, which in turn generates larger volumes of wastewater (flowback) that requires treatment and disposal;
- Has the potential to create induced seismic events and to disturb geological conditions as a result of hydraulic fracturing of rocks;
- Requires a larger number of production wells, with multiple wells drilled from one well pad and numerous pads across an area. As the risks are related mainly to the drilling and hydraulic fracturing operations, an increased number of wells increases the likelihood of environmental damage occurring;
- The transportation of water, chemicals, proppant and other items to the well pad and the transport of flowback, produced water and drilling fluids, from the pad have proven to be significant issues (e.g. in North America) presenting air quality (emissions and dust), noise and traffic impacts; and
- Wells are short-lived relative to those used for conventional gas extraction.

There is, in addition, greater public concern and public scrutiny of unconventional gas when compared to conventional oil and gas, due to the negative publicity generated by unconventional gas production, primarily in North America.

1.2.2 Study Objective

The objective of the study was to provide support for the development of possible Commission initiatives on managing potential impacts and risks associated with unconventional gas extraction in Europe. To this end, the project:

- Identified and assessed relevant measures, at the EU level, for preventing or managing the risks from unconventional gas developments;
- Prepared extended support for an impact assessment on the need and possible options for an EU risk management framework for unconventional gas; and
- Provided other support for developing possible measures and elements of a risk management framework.

1.3 Scope and Boundary of the Study

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

- Regulatory and technical analysis:
  - Summarise key risks and hazards, building on work conducted by AEA[9] for DG Environment;
  - Identify suitable measures to manage such risks.
- Support the development of policy options, in discussion with the Commission, to manage risks;
- Impact assessment: provide 'building blocks' supporting an Impact Assessment of the selected policy options in line with the Commission's Impact Assessment Guidelines; and
- Support for the development of a risk management framework: as required, provide technical or legal support to the development of a defined risk management framework.

It is not the purpose of the study to decide upon the most appropriate framework for managing the environmental risks of unconventional gas. Instead, the aim has been to provide information and data that can be used by the Commission in assessing the impacts of various policy options. The study provided 'building blocks' for a possible Commission Impact Assessment, in terms of the impacts of technical measures to address environmental risks and of the pros and cons of possible policy options.

This study has the following limitations:

- The focus of the study is unconventional gas exploration and production that uses high volume hydraulic fracturing and horizontal drilling (such as shale gas), referred to as 'unconventional gas' in this report. Other unconventional fossil fuels (such as tight gas, tight oil and coal bed methane) are not within the scope of the study;
- It should be borne in mind that there are currently few active unconventional gas projects involving the use of high volume hydraulic fracturing combined with horizontal drilling (such as shale gas) in the EU so current work has had to take into account expected future developments;
- A number of technical (and other) measures to address the potential environmental risks were identified. In the event of significant future unconventional gas development in the EU, many of these measures could be adopted without the need for any additional action at EU level. However, given uncertainty about what the future developments will look like, the application of these risk reduction measures cannot be assured, and in this study it has been assumed that measures will not necessarily be implemented if there is no EU-level requirement to do so. It is recognised that this approach tends to overestimate the likely compliance requirements and costs and thus measures that industry may adopt as normal practice are also considered in the analysis;
- Some of the technical measures that were assessed were straightforward to characterise and assign costs to (e.g. specific engineering-related controls on well design and maintenance). However, others were subject to much more uncertainty, related for example, to how the industry develops in the EU, taking into account local geographical and other conditions. There are therefore a number of limitations and uncertainties associated with some of the data presented here; and

[9] 'Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe', AEA 2013, report for European Commission, DG Environment

- 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.

1.4 Summary of Project Process

The project proceeded in a stepwise process entailing the identification of risks, the identification of measures that could mitigate the risks and review of the application of the *acquis communautaire* to establish whether or not those measures are already required by the current EU legal framework. This was followed by identification of measures that were considered non-business as usual (i.e. not required through application of the *acquis*) and an evaluation of associated costs and benefits (either qualitatively or quantitatively). Measures were then categorised by theme (see below). Policy options were first considered in broad terms. Combinations of measures were then selected by the Commission for a detailed assessment of four specific policy options.

1.5 Structure of Analysis

The report is presented in the following sections:

- Problem characterisation: the key risks of unconventional gas are summarised together with the existing regulatory setting at the European and selected Member States level. In addition, an indication of emerging voluntary actions by industry is noted and conclusions on the current ‘state of play’ are made;

- Measures to address risks and their impacts: the measures have been grouped by theme[10] within which an introduction to the risks of concern, an overview of possible measures and the impact of possible measures is presented;

- Policy options to deliver the measures: a description of policy options is presented followed by a more detailed assessment of potential options considering specific combinations of measures as selected by the Commission; and

- Conclusions.

[10] The themes are zoning, underground, chemicals usage, water depletion, surface water quality, air quality, waste, post-closure, public acceptance and other measures.

2. Problem Characterisation

2.1 Introduction

In this section, the nature of the problem is characterised through presentation of the principal environmental risks associated with unconventional gas exploration and production, the existing regulatory setting and expected and/or voluntary actions that may be taken by industry to address the risks. A conclusion on the current 'state of play' and need for further action is subsequently made.

2.2 Key Environmental Risks of Unconventional Gas

An extensive documentation and discussion of risks is presented in the AEA 2012 report prepared for DG Environment and is not repeated here. The potential causes of principal environmental risks that are specific to unconventional gas exploration and production or, whilst being common to other industries are potentially significant in scale for unconventional gas, are summarised by theme in the following table for reference.

Table 2.1 Potential Causes of Principal Environmental Risks Specific to Unconventional Gas Exploration and Production

Theme	Potential Causes
Underground	Well failure resulting in pollutants released from the well. Leakage or spillage of stored wastewaters. Introduction of pollutants due to induced fractures providing pathways to groundwater resources through either pre-existing man-made or natural structures. Induced seismicity and the potential impact on well integrity, creation of geological pathways for pollutants and possible minor earth tremors.
Chemicals usage	Inappropriate selection of chemicals in hydraulic fracturing and/or unsuitable assessment leading to unacceptable risks to the environment from releases. Lack of public/regulator scrutiny on specific chemicals used leading to unsuitable control of risks.
Water depletion	Extraction of groundwater or surface water for use in fracturing and the resulting quality and quantity impacts on groundwater and surface water bodies, linked ecological impacts and impacts on water resource availability.
Surface water quality	Leakage of stored wastewaters. Spillage of wastewaters.
Air quality	Emissions from diesel engines (vehicles, drilling rigs, etc.). Although such emissions occur from other activities (non-unconventional gas related), the significant scale of required mobile power generation at each site is specific to unconventional gas stemming from drilling and fracturing operations. Gases released from flowback and produced water if not flared or captured. Air pollutants (e.g. methane and hydrogen sulphide) released from the well (fugitive and/or flared and/or vented).
Waste	Improperly treated flowback or produced water leading to pollution of surface water: due to lack of proper characterisation or treatment plant not being suitable to treat contaminants.

Theme	Potential Causes
Zoning and landtake	Zoning i.e. well pads located unsuitable distances from aquifers, drinking water sources, residential areas, nature protection areas, etc. resulting in risks of, for example, of pollution to drinking water sources by chemicals used in fracture fluid.
	Land requirements for pad and pipelines and resulting impacts on removal of land for alternative uses (natural or anthropogenic) and ecology/environment impacts. Cumulative impacts may be significant.
Other aspects	Noise: although common to other activities (other than unconventional gas), noise risks are presented by unconventional gas from drilling, fracturing, flaring and vehicle movements.
	Site location and appearance: impact would vary depending on the landscape context (e.g. rural vs. industrial) and in particular due to cumulative impacts of large numbers of wells and pads.
	Traffic: although common to other activities, large numbers of vehicle movements are associated with unconventional gas from fracturing (water supply and flowback transportation for treatment) and the production phase (produced water for treatment).
	Potential for environmental impacts due to inadequate public scrutiny.

2.3 Regulatory Setting – Coverage and Gaps

The regulation of unconventional gas extraction can (and does) occur in different contexts within the EU. Whether the extent of regulation is sufficient to address all of the risks posed by these types of facilities is central to this study. Where regulation is insufficient, where there are gaps or where regulation is inadequately structured is where there could be justification for action at EU level. The regulatory context is examined here at two levels:

- The EU regulatory context; and
- Regulation at Member State level.

2.3.1 EU Regulatory Context

A number of laws in the environmental *acquis* are relevant in the regulation of unconventional gas facilities. Some are relevant to specific aspects of operation or to protection of individual parts of the environment, while others have wider application to the operation of the facility.

The main pieces of environmental EU legislation applicable to unconventional fossil fuels projects using hydraulic fracturing combined with horizontal drilling (such as shale gas) have been summarised by the European Commission services[11] and examined by the European Parliament[12].

An analysis of the existing *acquis* carried out for this project indicates that there are no major issues with regard to risks of operation on the surface if appropriate water, waste, nature protection, etc., legislation is applied and is

[11] Transmission note on the EU environmental framework applicable to shale gas projects at: http://ec.europa.eu/environment/integration/energy/pdf/legal_assessment.pdf

[12] 'Report on the Environmental Impacts of Shale Gas and Shale Oil Extraction Activities (2011/2308INI)', European Parliament, Committee on the Environment, Public Health and Food Safety, 25 September 2012

implemented. The following issues relevant to specific areas of EU environmental law can be highlighted however:

- There are requirements that are relevant across much of the *acquis* (e.g. SEAD, EIAD, Water Framework Directive, GWD), but these are not in sufficient detail or specific enough to address all risks arising from unconventional gas exploration and production;

- The MWD may enable measures to be required (through BAT and BREFs) but, with respect to emissions, not as extensively as under the IED/IPPCD. Permits under the MWD are therefore limited in their capacity to address all aspects;

- The scope of application of the IED to unconventional gas extraction at the exploration stage is uncertain due to the need to meet thresholds in the IED. It is possible that the IED would not apply in many cases;

- The IED provides a basis for adopting measures identified as BAT and elaborated in a BREF, but these are not comprehensive. The baseline required under IED is not sufficiently specific to unconventional gas as it is not applicable in all cases and as it only covers ‘soil’ and ‘groundwater’, but not deep underground;

- The Water Framework Directive is a limited basis for regulation as it requires the Member State (not the operator) to assess the quality of limited/selected bodies of water and due to the lack of project specific measures prescriptive with respect to operators, and the long timeframe (six years) for the review and update of River Basin Management Plans;

- Requirements for prohibited/restricted areas or buffer zones may only be implemented indirectly, at the SEA level (not project specific) and/or during EIA (project specific); and

- The *acquis* does not fully address the underground environment, geological, hydrogeological and induced seismicity aspects of unconventional gas extraction.

2.3.2 Member State Regulatory Context

This section is based on the conclusions of the report ‘Regulatory provisions governing key aspects of unconventional gas extraction in selected Member States’ (Milieu, 1st July 2013), which examined regulatory practices in eight Member States.

Milieu concluded that the selected Member States rely mainly on the general mining, hydrocarbons and environmental legislation and related permitting procedures to regulate unconventional gas activities and that there are few adopted specific requirements for this type of operation. However, it was noted that there are on-going reviews in a number of Member States aimed at addressing the specificities of unconventional gas exploration and production.

It was identified that there are legal uncertainties in existing Member State legislation. For example, regulation may be primarily focussed on water, industrial and/or mining waste law (or a combination, requiring operators to have several permits). As a result, the study concluded that requirements at national level are not only different, but sometimes contradictory. None of the Member States selected were found to have a specific regulatory regime for unconventional gas.

Regarding the main differences in Member State approaches and aspects of legal uncertainty and potential limitations identified, the following conclusions were reached:

- The status of EIA requirement for exploration and/or extraction (i.e. whether a full EIA is required or screening) differed amongst the individual Member States selected depending on how the EIA Directive requirements had been transposed and applied. Bulgaria and Denmark were found to have adopted new legislation requiring a mandatory EIA for unconventional gas exploration and/or extraction projects or projects involving the use of hydraulic fracturing;

- Details of financial guarantee requirements varied across countries;

- Areas of legal uncertainty were identified within national legislation (e.g. whether hydraulic fracturing should be controlled under a water permit and/or industrial installation permit and/or a mining waste permit and whether fracturing fluids remaining underground are considered as mining waste or not) leading to the application of different and sometimes contradictory requirements between/within Member States;

- Information disclosed or accessible to the public was found to be limited to general information associated with licensing and EIA processes;

- In the Member States selected, operators of unconventional gas activities were not obliged by law to disclose information to public authorities and the public on the substances planned for use during the fracturing phase. One Member State was noted to be considering requiring mandatory public disclosure;

- General requirements for geological characterisation designed for the extraction of conventional hydrocarbons were found to apply. However, it was found that these may not be specific enough to deal with the characteristics of unconventional gas extraction as they often do not focus on potential underground risks in the context of hydraulic fracturing (e.g. identification of existing faults and fractures; hydrogeology; existing abandoned wells);

- No specific requirements on baseline monitoring prior to drilling or fracturing were identified. Requirements were found to be set under the EIA procedure or permit conditions on an ad-hoc basis. No legal guarantee was found that such monitoring would be comprehensive enough to identify possible impacts from unconventional gas developments (e.g. migration of contaminants to groundwater, methane leakage);

- No legislation was identified in the selected Member States that explicitly addressed venting and flaring in the context of hydrocarbon projects. The competent authorities were found to retain discretion on deciding whether or not flaring and venting could be allowed;

- The study did not identify specific requirements relating to casing and cementing for unconventional gas wells beyond those applicable to conventional gas wells. Only two of the selected Member States were found to detail requirements on the design, construction and integrity for conventional gas wells;

- None of the countries assessed had set in place measures to control and monitor the effects of hydraulic fracturing in the ground with the exception of measures on monitoring induced seismicity in the UK and associated management practices;

- There was no common understanding across the selected Member States as to which sectoral legislation regulates the injection of fracturing fluids and, in some cases, there is a lack of or uncertainty as to the applicable requirements;

- None of the selected Member States provided particular requirements for the management of waste from hydraulic fracturing beyond the general waste and mining waste legislation. There were major differences between Member States, and uncertainties as to the applicable legislation and requirements regarding the different waste management options as illustrated by the following three points:

  - The selected Member States did not have a common understanding of the application of the transposition provisions of Article 11(3)(j) of the Water Framework Directive with regard to the injection of wastewaters resulting from hydraulic fracturing activities for underground disposal or with regard to re-use in subsequent fracturing operations, leading to potential contradictory approaches between Member States;

  - None of the selected Member States provided specific requirements for the treatment and discharge to surface waters of wastewater from unconventional gas projects; they were found to rely on legislation transposing the Water Framework Directive and the Urban Waste Water Directive;

  - None of the selected Member States had set specific requirements with regard to the surface storage of wastewater from unconventional gas activities; they were found to consider that surface storage of wastewater fell either under the MWD or could be subject to planning conditions for surface water storage.

- No specific requirements applied to the closure and post closure phase of unconventional gas wells beyond those applicable to conventional gas wells. For the latter, most Member States' legislation on conventional gas require a well abandonment plan and set post closure measures to be taken by the operator to maintain the integrity of the well; and

- To address the specificities of unconventional gas exploration and production, several Member States were found to have adopted or were reviewing their legislation or developing guidance focused on unconventional gas developments. Some competent authorities were also found to be calling for clarification from the European Commission on applicable legislation.

It can be seen that there is not only divergence of the practical regulation of unconventional gas extraction in the Member States, but also divergence in the interpretation of EU environmental law to address the challenges this type of facility places on regulators.

Regulatory uncertainties and gaps are prompting Member States to review legislation and draft new laws/permitting guidance. However, while some Member States may be adopting new approaches for the regulation of unconventional gas exploration and production, divergence is likely to continue and not all regulatory development at Member State level may deliver the necessary and required environmental protection. Also developments at Member State level run the risk of providing a fragmented regulatory framework across the EU. This could result in an uneven 'playing field' for business and increased business costs as individual companies adapt to different regulatory regimes.

2.4 Best Practice/Voluntary Actions by Industry

Potential best practice/voluntary actions by unconventional gas operators in Europe are beginning to emerge. Two examples are found in Det Norske Veritas' 'Risk management of shale gas operations – Recommended practice' (DNV, 2013) and the UK Onshore Operators' Group 'UK Onshore Shale Gas Well Guidelines. Exploration and Appraisal Stage' (UKOOG, Issue 1 February 2013). DNV's risk management approach provides an approach to the management of environment and safety risks. It stems from a traditional approach of identifying consequence categories, risk identification and assessment, engagement and communication of risk management with stakeholders and a management system to address risks. The approach focuses on the following areas:

- Health and safety risk management;
- Environmental risk management;
- Well risk management;
- Water and energy resources risk management;
- Infrastructure and logistics risk management;
- Public engagement and stakeholder communication; and
- Permitting.

The UKOOG guidelines focus on the exploration and appraisal stage only (i.e. not extending to the production and closure stages at this time). The approach of the guidelines is based on objective-setting rather than prescriptive requirements. It reflects the existing UK regulatory framework and addresses the following:

- Well design and construction;
- Fracturing/flowback operations;
- Environmental management (construction and operations);
- Fracturing fluids and water management;
- Minimising fugitive emissions to air; and
- A proposed format for the public disclosure of fracture fluids.

Both the DNV and UKOOG approaches are voluntary. The DNV approach stems from a classical risk management perspective that has been adapted and made specific to the risk aspects arising from unconventional gas and made available for use by the industry. However, obtaining industry-wide commitment to its application is not part of the approach.

The UKOOG guidelines stem from the industry in the UK and are a first attempt to set out and encourage the industry to operate to a consistent set of objectives (specific measures are not proposed) focussed on the early stages of development. The adoption of the objectives by industry is entirely voluntary, addressing the UK perspective.

In North America, where unconventional gas exploration and production is mature relative to Europe, the oil and gas industry has developed best practice guidance relating to unconventional gas extraction. This forms part of an overall management framework for unconventional gas, particularly if regulatory frameworks do not address all aspects. The International Energy Association's (2012) 'Golden Rules for a Golden Age of Gas' publication defines a number of key best practice elements for unconventional gas development and could make a useful contribution to developing industry practice in Europe. The Golden Rules cover the following key areas for industry:

- Measurement, disclosure and engagement;
- Site selection;
- Isolation of wells to prevent leaks;
- The responsible use and management of water;
- Elimination of venting and minimisation of flaring and other emissions;
- The need to 'think big' to realise economies of scale of innovative solutions and cumulative effect mitigation; and
- Ensuring a consistently high level of environmental performance.

The Golden Rules were developed with reference to best practice for unconventional gas developed by such organisations as the American Petroleum Institute, the Canadian Association of Petroleum Producers and the US Department of Energy. As with the DNV and UKOOG guidelines, adoption of the 'golden rules' is voluntary.

In conclusion, whilst best/recommended practice and voluntary approaches are emerging in Europe and becoming more developed in North America, they are not well established and fully integrated. The industry across Europe may be aware of best practices but there remains no coherent industry approach or agreement to implement a recognised set of objectives or practices.

Furthermore, in the absence of a developed industry in the EU and with a lack of commitment from an established industry to apply such measures, there is no guarantee that any voluntary approach would be implemented by any/many/all of the companies which in the future would become active in unconventional gas extraction.

2.5 Conclusions on the State of Play and the Need for Action

The EU environmental *acquis* and emerging best practice/voluntary approaches[13]variously address many of the risks posed by unconventional gas extraction at the surface if appropriate water, waste, nature protection, etc., legislation is applied and is implemented. However, this does not represent a coherent and comprehensive approach. Furthermore, there are gaps in the *acquis* in particular with regard to underground risks; emerging best practice and voluntary approaches attempt to address these gaps but do not guarantee that measures would be adopted either in part or in full by all operators.

With regard to national level regulation, the development of regulation at Member State level runs the risks of a lack of a level playing field for business. Moreover a number of unconventional gas plays extend across national borders as can environmental effects (e.g. air and water pollution). This presents a strong argument for some form of action or assistance at EU level to avoid or mitigate these impacts and risks.

A further point arising from developments at Member State level is one of timing. Due to the current development of the sector, some Member States are reacting now with various regulatory or non-regulatory responses. An early response at an EU level can help to support Member States in addressing the challenges raised by these activities.

[13] Refer to section 3.1.2 for a description of the approach to considering 'business as usual' risk mitigation measures that incorporate aspects of typical and best practice that may be adopted by the industry.

3. Measures to Address Risks and their Impacts

3.1 Introduction

3.1.1 Scope

In this section, the identified measures that could be applied to address the identified risks are described, together with their impacts. Consideration is given to economic, environmental and social impacts.

In many Impact Assessments, the benefits of possible measures relate to the avoidance/treatment of an existing environmental problem. However, in this case, with respect to benefits, measures are principally aimed at prevention of possible future 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). In assessing impacts it is assumed that the measures are fully implemented and, to the extent possible, the measures have been related to the elements of a likely typical development (the 'illustrative concession').

As set out in previous sections, the assessment of the potential impacts of the identified measures is intended to provide 'building blocks' for a possible Commission Impact Assessment, rather than a full Impact Assessment.

3.1.2 Measure Development and Categorisation

Measures to address risks and their impacts were developed based on: (a) the analyses of key risks and mitigation measures (which in turn drew substantially on a range of peer-reviewed literature), (b) an analysis of the *acquis* and whether it requires the identified measures to be implemented; (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 the project team to compare similar or 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

Measures were classified as either business as usual (BAU) or non-BAU. Those measures already required by EU legislation were classified as BAU (presented in Table E1 of Appendix E). If measures only *may* be required (i.e. there is uncertainty), then these were classified as non-BAU. For example, preparation and implementation of an emissions reduction plan for compliance with ambient air quality limit values (measure 16a) may be relevant if the IED applied to an unconventional gas site. However, as application of the IED to an unconventional gas site is 'conditional' (e.g. a technical connection to another IED site or activity above the IED Annex I thresholds), it is not *certain* that such measures would apply. Therefore, such measures were considered non-BAU.

It is acknowledged however, that many 'non-BAU' measures (i.e. not definitely required by EU legislation) might be adopted under normal practice by the industry. For example, key elements to maintain well safety such as blowout preventers, pressure and temperature monitoring and shutdown systems, etc. is not required by existing EU legislation, but it is expected that many operators would adopt these measures, as suggested by the Environment Agency for England[14] and DNV[15]. That certain non-BAU measures may be adopted by operators regardless of EU legislation (e.g. due to standard industry practice, or to minimise financial risk of investments) was an important consideration. To address this, non-BAU measures that were *likely* to be applied by industry regardless of legislative requirements were considered (presented in Table E2 in Appendix E). The degree of uptake of the measures by operators was then considered and (assumed, illustrative) uptake rates integrated into the analysis. 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.

Project Stage

The project team considered five project stages as follows:

- Stage 1 - Site identification and preparation: This stage includes site identification and selection; site characterisation – establishment of baseline conditions for air, water, land, geology/deep-ground conditions; initial evaluation of potential environmental impacts; initial development of geological conceptual model and geological risk assessment; exploratory boreholes for evaluation of geology and the reserve; seismic surveys; and securing of necessary development and operation permits;

- Stage 2 - Well design and construction, hydraulic fracturing and well completion: This stage includes pad construction and site preparation; pilot well drilling; initial horizontal wells drilled to determine reservoir properties and required well completion techniques; further development of geological conceptual model following test fractures; wellhead and well design and construction (drilling, casing, cementing, integrity testing); multi-stage hydraulic fracturing (injection of fracture fluid and management of flowback and produced water and emissions), and well completion;

---

[14] Environment Agency of England and Wales (2012), *'Review of Assessment Procedures for Shale Gas Well Casing Installation'*

[15] Det Norske Veritas AS (2013), *'Risk Management of Shale Gas Developments and Operations'*

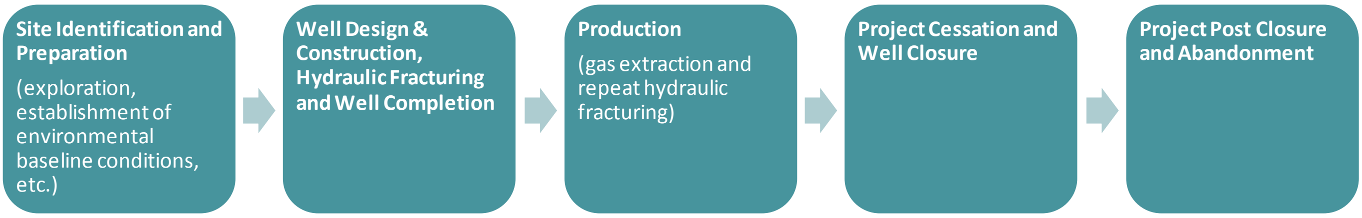
- Stage 3 - Production (gas extraction and repeat fracturing): This stage includes development of the field (including further pads, wells, pipelines and road infrastructure); management of produced water and emissions; repeat hydraulic fracturing (injection of fracture fluid and management of flowback and emissions), and environmental monitoring and well integrity testing;

- Stage 4 - Project cessation and well closure: This stage includes well plugging and testing; site equipment removal; site restoration and reclamation; and post closure environmental monitoring and well integrity testing; and

- Stage 5 - Project post closure and abandonment: This Stage includes pre-abandonment survey and inspection; and transfer of well to competent authority.

These stages are summarised in the Figure 3.1. Stage 1 and 2 focus on the exploration/appraisal phase of the development lifecycle. The scale and precise nature of activity in Stage 2 will vary dependant on the identified potential of the site to move to production (e.g. if initial fracturing results indicate poor potential of the site, operations may cease, the scale activity will be low and the site does not progress to production and further well development).

Figure 3.1 Measure Categorisation by Process Stage



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 refers to likelihood reduced to zero or negligible level, M refers to significant reduction in likelihood but still potentially foreseeable and L refers low to moderate reduction in likelihood. With regard to damage/consequence reduction, H refers to damage reduced to negligible level (no ascertainable damage to health/environment/property), M refers to damage reduced to a broadly acceptable level (e.g. compliance with expected standards in other fields) and L refers to low to moderate reduction in (potential) damage.

Level of ambition of each measure is then assigned by combining the different level of ambition from these two aspects (e.g. HH, ML, etc.).

Grouping by Theme

Measures have been 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) is to form coherent groups of measures and to understand at which stage of the process each measure may apply allowing for comparisons between similar or alternative measures as well as understanding possible risks they may address at that phase. This also allows comparisons to be made between measures of differing levels of ambition, which are often more restrictive or come at higher cost, to be taken into account in the Impact Assessment by the Commission.

Measures within each theme are presented in this chapter in the following common format:

- Introduction to risks of concern within the theme;
- Overview of possible measures – their characteristics, costs, description of measures combinations (complementary/redundancy[16]), comparative levels of ambition;
- Economic impacts – compliance costs. All costs presented are per pad and are annualised over 10 years with a discount rate of 4% (refer to 3.1.4 and Appendix B for details of a pad). In some cases, costs are derived from a whole illustrative concession cost and then converted to per-pad costs;
- Economic impacts – administrative costs;

[16] i.e. complementary measures can be applied in unison whereas other measures may become redundant with the application of another e.g. switching to grid electricity to reduce emissions from onsite power generation would make a measure requiring lean burn engines redundant whereas the assessment of potential future water demand would be complementary with a water management plan.

- Environmental benefits; and
- Social impacts (includes employment and the labour market, but also the effects on particular socio economic or demographic groups, community and personal assets, values and rights including access to public goods.

Detailed quantitative or qualitative descriptions of the measures are presented in Appendix D.

3.1.3 Assessment of Measure Impacts

The economic, environmental and social impacts of full implementation of each measure were considered (treated individually, not in a group). 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 experts. The experts included those with practical experience of unconventional gas projects in North America (including Marcellus Shale and others) and China, as well as experience of implementing conventional gas specific measures in the EU (e.g. surface water modelling, environmental impact assessment). When drawing from practical experience of unconventional gas projects in North America or China, the project team took into consideration the EU-27 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 Appendix B), which provided a unit in describing the potential scale of unconventional gas development in the EU-27. Where there was insufficient level of quantitative information or levels of uncertainty were too high, the impacts were discussed qualitatively.

A number of the measures considered in this section involve elements of information provision to competent authorities. There are several measures that involve what are clearly 'compliance' costs but which also include an element of 'administrative' costs. Furthermore, it is not clear in all cases whether certain costs should be considered as compliance costs or administrative costs. For example, costs related to monitoring of emissions or process parameters often relate partly to requirements for provision of relevant information to authorities (clearly administrative costs) but also relate to achieving compliance (e.g. managing processes to ensure that emissions are minimised). In the following sections – in the interests of consistency and convenience – costs of monitoring have generally been included within the category of administrative costs for operators.

3.1.4 Illustrative Concession

The concept of an 'illustrative gas concession' has been used in the present report, 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 an existing industry by which the impacts would be borne. Clearly future developments will vary substantially in size and the related impacts will therefore vary significantly. The illustrative concession is 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 concession includes 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 concession is presented in Appendix B and this has been used to inform the derivation of quantitative estimates of the impacts of measures.

3.1.5 Geographically Specific Aspects

Geographically specific aspects have been considered through a combination of measures addressing particular geographical locations/zones and the use of the illustrative concession approach. The illustrative concession takes into account the likely variability in key parameters, which could vary according to, for example, the available land area that could potentially be used for unconventional gas extraction (e.g. there could be greater constraints in more densely populated Member States or regions).

A number of measures relate to geographical considerations and, for example, the likely need to limit (or more tightly regulate) the development of unconventional gas in distinct locations/zones[17].

The assessment has deliberately avoided focusing on specific geographic regions of the EU given that (a) the future locations of developments in the EU are so uncertain and (b) any future risk management framework would need to be able to cover the full range of different geographical considerations. In relation to the latter point, the illustrative concession supports this approach by establishing the potential, general characteristics and parameters that may be expected in a full-scale unconventional gas play in the EU.

3.2 Zoning

Introduction to Risks of Concern

The illustrative concession (see Appendix B) is assumed to have an area of 800 km^2, comprise some 250 well pads, typically built some 1.5km from one another with each pad containing eight well. Each well pad is expected to require a site of some 2.24 hectares (above ground) once operational. The physical area occupied by well installations for hydraulic fracturing activity is likely to comprise less than 1% of the total concession area. Nevertheless the risks posed could be ameliorated by zoning (land use planning). Measures considered in this section include restrictions on operations in close proximity to incompatible existing/former land uses or to physical features (both above and below ground).

[17] 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, or within certain distances to specified sites, within 1,000m of abstraction points and aquifers for drinking water, within 1,600m of residential areas, schools hospitals and other sensitive areas, areas with abandoned wells and other potential pathways for fluid migration (distance specified on risk basis), water extraction areas for public drinking water supply, mineral spa protection zones and mineral water reserves.

Overview of Possible Measures

The measures are set out in Table 3.1, along with their level of ambition and applicable project stage. Given that the measures relate to site specific issues, all are assessed qualitatively. Fuller information on individual measures, information sources and assumptions is provided in Appendix D. The remainder of the section explores the costs and benefits associated with the measures.

Measures include prohibiting operations within specified sites, such as those with environmental designations, where extraction of public drinking water takes place or in areas liable to flooding. This includes locations with suspected groundwater contamination pathways; through old boreholes or left by former mining activities for instance. Measure 1a relates to the prohibition of unconventional gas activities in areas known to be unfavourable; whilst measure 1b would require additional controls, under the discretion of the relevant Member State.

Measures 26c, 40c, and 55e are likely to be addressed by Competent Authorities through strategic land use planning and in the allocation of concession areas, avoiding or limiting conflict between users and areas with known seismic activity. Measures 2f (i-v) and 26c require minimum distances to be established between extraction activities and sensitive land uses and activities, whilst 55i and N48 establish additional controls where operations are closer to the surface or in relative proximity to water aquifers. Measures 40a, 42b require operators to optimise the efficiency of their activities to limit environmental impacts.

Table 3.1 Measures to Address Risks related to Zoning

Measures		**Level of Ambition** [1]	**Stage** [2]					**Impact Assessment** [3]	**Notes**
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
ZONING									
42b	Location of sites close to existing pipeline infrastructure	LL	✓					Qualitative Assessment	
N48	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers and the surface to be determined based on risk assessment	MM	✓	✓				Qualitative Assessment	
26c	Fracturing to be a minimum distance from water resources	MM		✓	✓			Qualitative Assessment	
40c	High land, agricultural and ecological value locations avoided	MM	✓					Qualitative Assessment	
2f	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells 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	MM	✓					Qualitative Assessment	
2f	As above … Buffer zone from residential areas, schools hospitals and other sensitive areas of 1,600m	MM	✓					Qualitative Assessment	
2f	As above … Buffer zone within which detailed noise assessment is required of 305m	MM	✓					Qualitative Assessment	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
2f	As above … Buffer zone from abandoned wells and other potential pathways for fluid migration (distance specified on risk basis)	MM	✓					Qualitative Assessment	
2f	As above … Additional containment for sites near surface water supply locations	MM	✓					Qualitative Assessment	
40a	Optimisation from an environmental perspective, i.e. the number of wells, pad density and pad spacing	HM	✓					Qualitative Assessment	
40b	Compatibility with current and future potential land use (Natura 2000 sites, conservation sites, human use, industrial use, appropriate zoning, CCS, geothermal, water abstraction)	HM	✓					Qualitative Assessment	
1b	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	HM	✓					Qualitative Assessment	
55e	Avoid high seismicity risk areas	HH	✓					Qualitative Assessment	
55i	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*	HH		✓	✓			Qualitative Assessment	
55i	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*	HH		✓	✓			Qualitative Assessment	
1a	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	HH	✓					Qualitative Assessment	

Notes
1. For key to level of ambition, refer to section 3.1.2.
2. Stage 1: Site identification and preparation. Stage 2: Well design & construction, hydraulic fracturing & well completion. Stage 3: Production (gas extraction and repeat fracturing). Stage 4: Project cessation and well closure. Stage 5: Project post closure and abandonment. For full descriptions refer to section 3.1.2.
3. Costs are in 2012 prices, annualised over 10 years with a discount rate of 4%. For definition of Low and High ambition, refer to Appendix D

Economic Impacts – Compliance Costs

All measures in this section have been considered qualitatively as they are not possible to assess due to zoning aspects requiring reference to the specific local situation. Collectively, the measures are likely to result in Member State Governments identifying areas/zones in which production is prohibited or significantly curtailed. The major economic costs therefore will be 'lost' production opportunities. These areas are likely to be identified before production starts, however.

In certain cases the measures may serve to limit or restrict the scale, extent or duration of permitted operations. These cases would appear to be less common. Measures 1a and 1b restrict site selection and operational flexibility. Additional costs are likely to be incurred by operators in initial site identification and appraisal, including well viability assessments. Potentially significant unrecoverable costs could be incurred if an area needs to be abandoned or activity curtailed as circumstances change although the measures are equally likely to prevent such losses being incurred. The measures may also reduce the overall quantum of gas development, per play. Similar costs are likely to be incurred through compliance with measures 2f, 26c, 55i and N48. These relate to a series of 'buffer zones' or increasingly stringent permit requirements, where hydraulic fracturing is in proximity to water abstraction points, aquifers or sensitive locations such as schools and hospitals.

Measure 40a aims to 'optimise' the physical location of well pads, their spacing etc, to minimise cumulative environmental and social effects. Pads and other operations will need to be situated to take account of sensitive areas and receptors. As above, additional site identification costs are likely to be incurred alongside some potential lost revenue if extraction of gas reserves are limited. The measure may also serve to focus investment in those areas where there are fewer cumulative impacts, however.

Measures 40c, 42b, and 55e seek to avoid conflict between unconventional gas activities and high value land uses or where seismic activity poses a risk (e.g. to well integrity or private property through induced seismicity), including consideration of the requirements for potential future land users (measure 40b). As above, costs are likely to be borne through the need to procure more sophisticated initial site appraisal/assessment, or potentially abandoning sites as a result of site characterisation assessment. Some lost revenue may arise where access to gas reserves is limited; but again, such measures are likely to save some investment costs, through for example reducing the risk of land use conflicts, major accidents and lowering insurance costs.

Economic Impacts – Administrative Costs

Competent authorities would incur costs defining the areas in which these measures should apply and production prohibited or curtailed. These may be identified through Strategic Environmental Assessment (SEA) for instance, where potential zoning conflicts are considered in detail. These include measures 1a, 1b or 55e. Several measures relate to specific risk management requirements that will either only be known after site characterisation (such as N48) or will require site characterisation to identify appropriate mitigation and permit conditions (such as 55i). Costs include liaising with operators and considering individual applications. As with the operators, the measures are likely to avoid or minimise major conflicts over land use and reduce the likelihood of major contamination of drinking water, ultimately saving the costs associated with managing such problems.

Environmental Benefits

The measures reduce the likelihood and scale of environmental risks by restricting or precluding unconventional gas activities in sensitive areas. These include those prone to seismic activity, those covered by environmental designations or in proximity to drinking water abstraction points and aquifers. Optimisation of well pad spacing also limits transport and related energy use. The measures protect existing land use designations and aim to minimise land use conflicts.

Social Impacts

The measures effectively limit operations in certain areas. The measures would not necessary result in employment loss, but may result in a degree of forgone employment by restricting the total number of wells that are either viable or could be exploited. By protecting (or avoiding conflict with) nearby land uses, including agricultural activities, employment in these activities would be protected. Moreover, in certain circumstances, future employment may well be protected (see measure 40b) by requiring operators to consider implication for future land uses, such as geothermal energy production, water abstraction or other employment generating activities.

A number of measures restrict activity in sensitive areas. These serve to effectively protect public goods, such as areas protected by environmental designations, open spaces, national parks and locations with ecological significance. The measures protect both physical integrity but also against noise, visual impact and risk to public health and safety from accidents, including induced earth tremors and potential subsidence.

Potential Effects on House Prices

People's homes are typically their largest asset. The measures considered may affect house prices, directly and indirectly depending on circumstance. Gas exploration and production is likely to have an adverse effect on local land values and house prices where such activities take place in proximity to residential areas. They may also have an effect on commercial property and adversely affect, delay or alter potential development. The ability of affected people to obtain insurance, or secure or renew bank loans or mortgages may also be affected. Losses in property value would often delay relocations. Such potential or actual land use conflict and its effect on house prices is essentially a zoning issue, hence is considered here.

The duration of these adverse affects may well be temporary, but would depend on the duration between concession grants, environmental assessment, permitting, construction and operation. The extent of any permanent effect on house prices would ultimately depend on public confidence in the industry and in the risk management measures taken.

3.3 Underground Risks

Introduction to Risks of Concern

Well drilling, hydraulic fracturing and production of unconventional gas pose risks related to groundwater contamination, to the integrity of rock formations and to the likelihood, scale and frequency of induced seismic activity. These risks, collectively referred to as underground risks, are considered in this section. The illustrative gas concession Appendix B) indicates that horizontal wells may extend some 1,350 metres horizontally from the well and 3,000 metres vertically. Each well pad requires around six hectares of land above ground during the construction phase and a little over two during operation. Below the surface operations may reach some 300 hectares in total, per well pad. Drilling activities typically last for some 50 days with fracturing occurring twice per well over a 10 year lifetime.

Given the nature of activities, there is a large number of underground risk measures considered. As such, these have been categorised into four areas. First, those requiring additional organisational capacity, activities or responsibilities either from operators, Competent Authorities, Members States or the European Commission. Second, those related to investigations of underground geological, hydrological or seismic conditions. Third, those related to operational risk management and mitigation, including well safety, risk in the event of mechanical failure or human error, including contingency planning. And fourth, ongoing monitoring of underground conditions.

Overview of Possible Measures

The measures have been categorised and set out in Table 3.2 along with their level of ambition, applicable project stage and whether they have been assessed qualitatively or quantitatively. Measures are as follows:

i) **Organisational capability (public agencies and operators):** these measures focus on increasing the general level of awareness of potential risk in any given location or gas play. They require open communication with operators sharing data and experiences, with Competent Authorities enabling, coordinating and mandating information sharing. This includes awareness of potential cumulative or systemic risks associated with unconventional gas extraction alongside other underground activities and developing specific guidance to ensure adequacy of risk assessment;

ii) **Investigations of underground conditions (including geology, hydrology and seismicity):** measures focus on tests to ascertain underground conditions against which any change in conditions could be compared. Hydrological surveys include groundwater sampling, in situ fluid pressure and modelling of fluid flows and potential underwater migration. Geological surveys include data on underground mapping, cross sections and identification of fractures, rock strengths, thickness and permeability. Seismic surveys include analysis of seismic history, surface measurements of seismic activity and underground 2D and 3D surveys to identify geological characteristics. Identification of methane gas near the surface and of existing underground wells/structures is also required;

iii) **Operational risk management and mitigation:** measures focused on risk *management* measures include ongoing contingency planning and remedial actions in the event of well failure. Operational risk *mitigation*, includes well safety (blowout preventers, pressure and temperature monitoring and fire and gas detection systems); ongoing well integrity testing; minimum distances between formations and people; minimum vertical distances between wells and aquifers; modelling to predict the likely extent of fracture growth; pre-injection testing and ground prediction modelling to assess the implication of potential earth tremors; and monitoring and/or the use of alternative fracturing approaches to reduce the risk of pollution;

iv) **Monitoring of underground conditions:** measures related to the ongoing monitoring of various underground conditions, including groundwater, induced seismic effects and gas seepages.

Table 3.2 Measures to Address Underground Risks

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
UNDERGROUND RISKS									
i)	***Organisational capability (public agencies and operators)***								
N44	Competent authorities compile regional maps of underground resources	LL	✓	✓	✓	✓	✓	Qualitative Assessment	
28d	Sharing of information to ensure that all operators in a gas play are aware of risks and can therefore plan	LM	✓					Qualitative Assessment	
N45	Members States establish a capability to address groundwater contamination arising from unconventional gas operations. In the case of transboundary aquifers, joint capability established	LM	✓	✓	✓	✓	✓	Qualitative Assessment	
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)	ML	✓	✓				Qualitative Assessment	
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	MH	✓	✓	✓	✓	✓	Qualitative Assessment	
ii)	***Investigations of underground conditions – geology, hydrology and seismic conditions***								
N55	Conduct 2D seismic survey to identify faults and fractures	LM	✓	✓	✓			1,700	
22d	Search for and document potential leakage pathways (e.g. other wells, faults, mines)	MM	✓					Qualitative Assessment	
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	MM	✓					4,300	
55c	Ground motion prediction models to assess the potential impact of induced earthquakes	MM	✓	✓				1,400	
3a iii	Site baseline: Undertake sampling of groundwater Low Ambition: Sampling of shallow groundwater during wet and dry periods	HH	✓					900	
3a iii	Site baseline: Undertake sampling of groundwater High Ambition: Borehole to sample deep groundwater and characterise the hydrological series	HH	✓					147,900	
3a x-a1	Site baseline: Geological, hydrogeological and seismic conceptual model [1] Obtain and analyze seismic (earthquake) history.	HH	✓					400	
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	HH	✓					400	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
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 to low ambition, obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures through new cores and stratospheric tests	HH	✓					35,800	
3a x-a3	Site baseline: Geological, hydrogeological and seismic conceptual model [3] Undertake surface microseismic survey	HH	✓					4,800	
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	HH	✓					6,800	
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 over 10,000 years	HH	✓					8,800	
3a x-a5	Site baseline: Geological, hydrogeological and seismic conceptual model [5] Develop maps and cross sections of local geologic structure	HH	✓					400	
3a x-a6	Site baseline: Geological, hydrogeological and seismic conceptual model [6] Conduct 3D seismic survey to identify faults and fractures	HH	✓					44,400	
3a x-a7	Site baseline: Geological, hydrogeological and seismic conceptual model [7] Obtain data on area, thickness, capacity, porosity and permeability of formations	HH	✓					200	
3a xiii	Site baseline: Undertake assessment of existing underground wells and structures Low Ambition: Undertake assessment of underground wells and structures	HH	✓					100	
3a xiii	Site baseline: Undertake assessment of existing underground wells and structures High Ambition: In addition to Low Ambition, 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	HH	✓					400	
3a xi	Establish the presence of methane in groundwater, including drinking water (baseline)	HH	✓					Qualitative Assessment	
iii)	***Operational risk management and mitigation***								
26e	Modelling of fracturing programme to predict extent of fracture growth based on best information	MM	✓	✓	✓			7,600	
26g	Implementation of remedial measures if well failure occurs	MM		✓	✓	✓	✓	Qualitative Assessment	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
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)	MM	✓	✓	✓			9,900	
N05	Initiate immediate flowback post fracturing	MM		✓	✓			Qualitative Assessment	
N07	Operator to use alternative fracturing fluids to water (e.g. nitrogen, CO_2, propane)	MH		✓	✓			Qualitative Assessment	
55h	Smaller preinjection prior to main operations to enable induced seismicity response to be assessed	MH		✓				Qualitative Assessment	
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)	HH		✓	✓			863,000	
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)	HH		✓	✓	✓		5,100	
22b ii	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: ii) pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing	HH		✓	✓	✓		1,300	
22b iii	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: iii) mechanical integrity testing of equipment (MIT)	HH		✓	✓	✓		11,300	
22b iv	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: iv) casing inspection test and log	HH		✓	✓	✓		43,200	
22c	Multiple barriers between the target formation and people/the environment, including minimum vertical distance between target formation and aquifers	HH	✓	✓				Qualitative Assessment	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
	iv) Monitoring of underground conditions								
3b iii	Monitoring; Undertake monitoring of groundwater Low Ambition: Sampling of shallow groundwater during wet and dry periods	MM		✓	✓	✓		1,400	
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	HH		✓	✓			10,000	
55d	Microseismicity monitoring and management requirements during operations Low Ambition: Real time monitoring of microseismicity during all operations	HH		✓	✓			600	
55d	Microseismicity monitoring and management requirements during operations High Ambition: As Low Ambition, plus cessation of fracturing if specified induced seismic activity is detected (using traffic light system)	HH		✓	✓			Qualitative Assessment	
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 (utilises boreholes from baseline establishment)	HH		✓	✓	✓		11,000	
3b xvii	Monitoring: Undertake monitoring of induced seismicity from fracturing	HH		✓	✓	✓		12,000	
3b xviii	Monitoring: Undertake monitoring for presence of methane seepages in groundwater, including drinking water.	HH		✓	✓	✓		Qualitative Assessment	

Notes
1. For key to level of ambition, refer to section 3.1.2.
2. Stage 1: Site identification and preparation. Stage 2: Well design & construction, hydraulic fracturing & well completion. Stage 3: Production (gas extraction and repeat fracturing). Stage 4: Project cessation and well closure. Stage 5: Project post closure and abandonment. For full descriptions refer to section 3.1.2.
3. Costs are in 2012 prices, annualised over 10 years with a discount rate of 4%. For definition of Low and High ambition, refer to Appendix D.

Economic Impacts

The remainder of the section summarises the costs associated with the measures. For full details of measures, including costs, information sources and assumptions, the reader is referred to Appendix D.

Organisational Capability (public agencies and operators)

This section focuses on capabilities associated with administration; compliance costs are nil or negligible. All costs have been considered qualitatively, as follows:

- **Operators:** costs include staff time required liaising with other operators and third parties including regulators and sharing data/experiences. The aim is to accelerate learning rates and to avoid repetition of mistakes/failures. Staff resources would also be required for briefing employees and adjusting operating practices as necessary; and

- **Authorities:** procedures for dealing with major incidents must be established and tested. This would involve some liaison with similar officers/units in adjoining Member States, given the potential international scale of environmental effects. Authorities would need to allocate sufficient officer time to develop, consult on and publish relevant risk assessment guidance. Additional measures require information sharing and liaison alongside the collection collation and publication of data, such as resource maps.

Investigations of Underground Conditions - Geology, Hydrology and Seismicity

This section focuses on technical surveys on underground conditions. Compliance costs are nil or negligible. Administrative costs are considered both qualitatively and quantitatively, as follows:

- **Operators: v**arious baseline assessments relating to underground conditions. These include:

  - **Groundwater survey (3a iii):** costs have been included based on low and high ambition. Sampling during both wet and dry periods (low ambition) is expected to cost some €900. At depths over 400m a borehole is likely to be required, where costs could be at some €150,000. These costs also include staff costs for a search and documentation of potential leakage pathways (22d);

  - **Micro-seismicity including conceptual model of geological conditions:** this measure comprises seven elements (see 3a x [1-7]). These are quantified individually in Appendix D. These costs include the development of a conceptual model of the zone before work. The cost of annual updates of the conceptual model (26d) is estimated at some €4,300;

  - **Establish presence of methane (3a xi):** the costs for this measure are included in costs for the groundwater survey (3a iii above) and in measure 3a iv - costs for identifying water abstraction points, which is covered in the 'Other measures', section 3.11;

  - **Assessment of underground wells and structures (3a xiii):** the low ambition measure involves analysis from well history databases and associated geologist labour time, which is estimated at some €100. The high ambition measure is as above plus a desk study to evaluate integrity of construction and a record of completed and/or plugging of existing shallow wells (e.g. for water abstraction). These costs are estimated at some €400;

  - **Ground motion prediction models to assess impact of induced earth tremors (55c):** The cost is estimated at some €1,400;

  - **2D seismic survey to identify faults and fractures (N55):** Here the cost is estimated at some €1,700.

- **Authorities:** There would be some costs incurred with administration and regulation associated with these activities.

Operational Risk Management and Mitigation

Compliance Costs

- **Key capital investments related to maintenance of well safety (22a).** Specific actions include blowout preventers, pressure and temperature monitoring shutdown systems. These are standard industry practice design, but are not specific requirements under existing regulation. Total costs are estimated at €863,000;

- **Integrity testing is covered in Measure 22b** comprises various elements:

  - Wire line logging (calliper, cement bond, variable density): €5,100;

  - Pressure (between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing €1,300;

  - Mechanical integrity testing of equipment (MIT) €11,300;

  - Casing inspection log to determine the presence or absence of any casing corrosion: it is assumed the tests are carried out once (after the cement work). Total cost is some €43,200.

- **Maintain multiple (vertical) barriers between the target formation and people/the environment, including minimum vertical distance (e.g. 600m) between target formation and aquifers (22c).** Costs depend on site specific characteristics. The measure aims to avoid unintentional penetration of rock strata that may provide a pathway to aquifers or subsurface geological storage sites. Maintaining such barriers may serve to reduce the amount of resource available for extraction per well and hence reduce revenue. Costs would also be incurred through assessing presence of suitable geological barriers and controlling of fracture distance, which would be undertaken on a site by site basis;

- **Small-scale pre-injection tests and monitoring of the seismicity response (55h**). If a significant (e.g. unexpected or large scale) response is found from the tests, re-evaluation of the site or changes to operations may be required if it is suggested that induced seismicity from full-scale fracturing could result in environmental pollution (e.g. through activation of faults and rock fractures that facilitate pollution of overlying aquifers). Operators would incur costs (which are qualitatively assessed) these relate to the costs of the mini-fracture itself; potential delays to full scale production and potential well abandonment with associated sunk costs and lost revenue;

- **Immediate flowback post fracturing (N05**). The incidence of earth tremors resulting from fluid injection increases in proportion to the volume of injected fluid. Reducing the volume of fluid injected reduces the probability of significant earth tremors. Given that flowback is implemented after fracturing, a change to immediate flowback of fracture fluid following fracturing rather than allowing a period of time to pass prior to flowback will incur insignificant/negligible cost. It appears this measure could be implemented at low cost, with the potential for reducing the likelihood of earth tremors, subject to specific operational needs;

- **The use of alternative fracturing fluids** (including the use of gases) is under ongoing investigation. Their use would increase as and when techniques become technically and commercially available with the aim of reducing environmental risk. These may include the **use of nitrogen, CO_2 or propane for fracturing (N07).** Operators would be required to evaluate emerging techniques against 'traditional' hydraulic fracturing. Costs would include research and trials, internal evaluation of environmental risks and the development of any technology associated with their use;

- **Develop and maintain contingency plans to address foreseeable impacts (N09).** Costs have been estimated based on labour costs associated with their preparation. This would require: risk identification; evaluation of risks; development of necessary contingency plans; consultation and testing with Competent Authority and Emergency Services; defining approach to investigative approach and corrective action; along with reporting. Overall costs are estimated at €9,900 (assuming the risks are materially different between pads and/or require consultation with different Authorities);

- **Implement remedial measures if well failure occurs (26g)** requires operators to plan and budget for remedial actions such as: well reconstruction/repair; well abandonment (i.e. implementing the required abandonment process); and closure and lost operational time and production.

Administrative Costs

This sub-section of measures focuses on operational risk management and hence the focus is on compliance costs. Administrative costs would also be incurred by both operators and authorities.

- **Operators: model fracture programme to ascertain the extent of potential fracture growth (26e**). Modelling natural fractures would be based on the Discrete Fracture Network (DFN) approach and include dynamic response (e.g. hydro-shearing) to simulation. In unconventional gas, the model would include tensile fracture, (growth depends on the mechanical properties of the rock, in situ stress, applied forces and on leak off of fluids through the formation and natural fractures, using Finite Element Analysis (FEA) or Discrete Element Method (DEM)). 3D fracture modelling integrated with geomechanics model would be approximately €7,600 per model;

- **Authorities:** there would be some costs incurred with administration and regulation associated with these activities, for instance applications for development consent and/or environmental permitting would become more detailed, and additional information would need to be provided and this would have to be reviewed and assessed by staff. Similarly, conditions associated of operations would increase which would need to be specified in documentation (and potentially be made public).

Monitoring of Underground Conditions

Compliance Costs

This section focuses on ongoing monitoring/technical surveys associated with underground conditions which are classified as administrative costs. Compliance costs are nil or negligible.

Administrative Costs

Costs are considered qualitatively and quantitatively. The majority of costs incurred are administrative costs.

- **Operators: groundwater monitoring (3b iii)** has been quantified. The low ambition measure assumes monthly sampling, during both wet and dry periods (at 1 sample per month, 12 months) during drilling and fracturing operations only. The samples would be analysed 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. Costs are estimated at €1,400 for equipment and labour costs. The high ambition measure relates to the establishment of a deep groundwater sampling network to establish its relevant characteristics. This is estimated at some €11,000 (assuming the use of boreholes constructed during baseline establishment);

- **Monitoring for induced seismicity (3b xvii)** requires cost of passive seismic equipment and labour, collectively costing some €12,000. The costs for similar monitoring for the presence of gas seepages (3b xviii) are included in measure 3b iii (and measure 3b iv which is included under 'other' measures in section 3.11);

- **26f is monitoring and control during operations to ensure hydraulic fractures/pollutants do not extend beyond the gas-producing formations, result in seismic events or damage to buildings/installations**. A geophone array is excepted to be required, already accounted for in Measure 3b xvii, but additional labour costs are estimated at some €10,000;

- **Micro seismicity monitoring and management requirements during all operations (surface and in borehole monitoring to assess fracture growth and direction) (55d).** This measure also requires geophone array (quantified under 3b xvii) and aligns with tasks listed under measures 3a x (baseline micro seismicity and geological conceptual model). Costs are associated with additional operator time, estimated at €600. The high ambition option involves cessation of fracturing activity if induced seismicity activity is detected, with associated loss of revenue if fracturing is delayed or ceases, which may be substantial; and

- **Authorities:** There would be some costs incurred with administration and regulation associated with these activities.

Environmental Benefits

Certain measures considered above directly limit the magnitude of environmental effects, others seek to remove them. Those related to organisational capacity and freedom of information aim to achieve consistency in environmental and risk assessment and accelerate learning rates. The intention is that the likelihood of major incidences or unforeseen/unintended effects reduces at a faster rate than would otherwise be the case. These effects could include groundwater/aquifer contamination or events linked to induced seismicity. If fully implemented the effect would be to reduce significantly potential adverse impacts to the quality of groundwater, including drinking water.

Investigations of underground conditions ensure operators have a sound understanding of hydrology, geology and the likelihood and severity of potential seismic activity, against which changes could be monitored on an ongoing basis. The measures deliver site specific benefits enabling accurate predictions of the likely effects and scale of risk to groundwater and to rock formations. They too also accelerate learning rates as more information becomes available and is shared. This second set of measures reinforces the first.

Operational risk management and mitigation measures reduce the likelihood of well failure resulting in significant underground and surface contamination. They require changes to business operation and reduce the likelihood and scale of environmental risks, including unintentional introduction of chemicals underground. These measures focus on structural well design and integrity testing, smaller 'pre-injection' tests to empirically observe the effects of rock strata, alongside physical distancing between well activity and groundwater/local communities and to limit the period during which groundwater could be in contact with fracturing liquids through immediate flowback.

Social Impacts

This section considers potential effects on people. This includes employment and the labour market, but also the effects on particular socio economic or demographic groups, community and personal assets, values and rights including access to public goods. By imposing certain obligations on both operators and public authorities the measures considered both safeguard existing employment and support the creation of additional jobs.

The capital requirements incurred by business would influence decisions on individual well viability, in certain cases the costs imposed may mean commercial development is not viable (i.e. foregone employment), in isolation the measures would appear likely to result in additional employment opportunities. The operational requirements on well integrity, for example, would increase demand for specifically qualified construction labour. It is likely that these jobs would be filled by contractors; (many of which are classified as SMEs) and of which the majority are typically male.

The baseline studies are likely to require the use of technical consultancy/environmental assessors in a range of disciplines. The measures do not directly enhance job quality, but enhance employee safety and that of adjoining communities. Access to the labour market and to equality of opportunity are not addressed and would depend on job training and recruitment schemes carried out by construction and technical firms and any service providers. Whilst not related to risk, specifically, such effects should be considered within socio-economic analysis in environmental impact assessment, for instance.

Detailed testing and analysis of groundwater conditions and the potential for leakage into aquifers limits the potential for transboundary or effects arising from drinking water contamination such as loss of water resources availability for communities.

3.4 Chemicals Usage

Introduction to Risks of Concern

Typically chemical additives account for around 0.5% but up to 2% of fracturing fluids and may thus account for 75-300m^3 of chemical additives for a single well using in the order of 15,000m^3 of fracture fluid[18]. They include, for example, surfactants, corrosion/scale inhibiters, biocides, friction reducers, acids and others[19]. Some of the chemicals used would remain underground while some would return to the surface in flowback water.

The primary risks of concern with chemicals used in unconventional gas extraction relate to the potential release to the wider environment and subsequent exposure of people or contamination of water resources and other

[18] JRC (2012): Shale Gas for Europe – Main Environmental and Social Considerations – A Literature Review, European Commission Joint Research Centre, 2012.

[19] FracFocus (2012): Information and insights about the ingredients in a well's hydraulic fracturing fluid, http://blog.aapg.org/geodc/?p=2565, 3 October 2012.

environmental media. This may occur through underground release pathways, releases at the surface resulting from spills and accidents or through presence in flowback water and subsequent release.

Historically, some of the chemicals that have been used in unconventional gas extraction are classified as hazardous according to EU legislation (CLP Regulation and Groundwater legislation). The box below provides some commentary on the extent to which hazardous chemicals are used (or are likely to be used) in fracturing fluids.

Box 1 Hazards and Risks of Chemicals used in Hydraulic Fracturing

Health and Environmental Hazards of Chemicals

Historically, a huge number of chemicals have been used in hydraulic fracturing, in different wells across the USA in particular. A list derived from a publication by the US EPA (2012) includes around 900 different chemicals, of which a significant proportion are likely to have had relevant health and or environmental hazards (the list includes e.g. benzene, naphthalene, toluene and xylene). However, it is thought that many of these chemicals are no longer used.

Looking at those substances used more recently, of 43 substances listed as most often used in the USA (FracFocus, 2013), a number of these substances are classified for relevant health and environmental hazards (either ‘harmonised’ or ‘notified’ classification under CLP):

- In terms of health hazards, 15 were classified for acute toxicity via the oral route, of which seven were in the more toxic categories (fatal or toxic if swallowed); eight were classified for acute dermal toxicity, of which five were in the more toxic categories; 10 were classified for acute inhalation toxicity of which five were in the more toxic categories; 20 were classified for skin irritation/corrosion of which 12 were classified as having potential to cause severe skin burns and eye damage; likewise 20 were classified for serious eye damage or irritation. No substances were in the more severe categories for carcinogenicity and mutagenicity, though two were ‘suspected’ of causing cancer. Eight substances were classified for reproductive toxicity, all of which were in the highest hazard category.
- In terms of environmental hazards: five were classified as very toxic to aquatic life (acute toxicity) and seven were classified for chronic toxicity and possible long-lasting effects on aquatic life).

It is possible that chemical formulations used in hydraulic fracturing in the EU could be quite different from those used in the USA. Some companies have produced ‘European’ fracturing formulations and initial evidence is now emerging on chemicals that are being used in (largely exploratory) wells in the EU. By way of example, from these sources:

- Some wells drilled so far (NGS, 2013) have used substances such as hydrotreated light distillate/kerosene (which has EU-wide classification as a category 1 aspiration hazard, but some of the chemical suppliers classify it as a category 1B carcinogen) or glutaraldehyde which has EU harmonised classification as (amongst others) a category 1 respiratory sensitiser and category 1 acute aquatic toxicity.
- One chemical supplier’s European formulation included e.g. a substance classified for reproductive toxicity (H360 – may damage fertility or the unborn child) as well as other substances with various other health hazards and environmental hazards (e.g. substances that are classified as toxic to aquatic life with long-lasting effects).

Distinguishing Hazards from Risks

It is clear from the above that substances that are classified for certain adverse health and environmental hazards may well be used in hydraulic fracturing in Europe. However, the fact that a ‘hazard’ is present does not necessarily mean that there is any realistic ‘risk’ to people or the environment:

- When present in hydraulic fracturing fluids, the substances in question are often likely to be so diluted that the ‘mixture’ of those chemicals in water may no longer need to be classified as hazardous according to EU legislation.
- The fact that there is a hazard present does not necessarily mean that there is a realistic pathway through which humans and the environment could be exposed in harmful quantities.

On the basis of the above, a number of measures related to assessing (and managing) the risks associated with chemicals used in hydraulic fracturing are included here, particularly through existing legislation such as REACH and the biocidal products regulation, which are intended to be the vehicles through which the safe use of chemicals and biocides is assured.

However, it is also important to recognise that some other regimes regulate certain hazardous chemicals on the basis of hazard alone (on the basis that eliminating the hazard de facto also removes/reduces the risk). This is the case for example in the case of restrictions on certain hazardous substances in electrical and electronic equipment. Similarly, both the REACH and biocides legislation include a presumption that the most hazardous substances should not be used unless a specific authorisation is granted for specific uses (e.g. for substances of very high concern under REACH). Measures that would involve substitution of hazardous chemicals have also therefore been included.

Sources: US EPA (2012): Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources, United States Environmental Protection Agency Office of Research and Development, Progress Report, EPA 601/R-12/011, December 2012.

FracFocus (2013): http://fracfocus.org/chemical-use/what-chemicals-are-used accessed 7 June 2013.

NGS (2013): NGS Facts – Disclosed wells, International Association of Oil and Gas Producers, http://www.ngsfacts.org/findawell/list/ accessed 4 July 2013. Information on classifications above was based on the European Chemical Agency's Classification Labelling and Packaging inventory database.

Supplier European formulation: http://www.halliburton.com/public/projects/pubsdata/hydraulic_fracturing/fluids_disclosure.html , accessed 7 June 2013.

The potential risks specific to unconventional gas extraction are not necessarily fully addressed through existing EU legislation such as the REACH Regulation and biocides legislation. The specific chemicals used would vary widely according to the geographical location (e.g. rock geochemistry) and the stage in a well's development.

Under existing EU policy, chemicals that are manufactured or imported at over 1 tonne per year must have a REACH registration[20] including chemical safety assessment to demonstrate safe use (by the chemical manufacturer/importer), with downstream users such as unconventional gas companies required to comply with relevant risk management measures. Similar provisions apply to biocides. However, there is a concern that the chemical safety/risk assessment may not sufficiently consider the specific risks and environmental pathways associated with unconventional gas.

Chemicals that are not registered under REACH for the relevant use (or biocides without approval of the active substance and authorisation of the associated biocidal products) cannot be used and substances that are subject to EU-wide restrictions (Annex XVII) or 'substances of very high concern' without authorisation (Annex XIV) of REACH cannot be used. However, there are still many chemicals that are classified as 'hazardous' that could still be used in principle.

Furthermore, in other geographical areas, a lack of disclosure of information on specific chemicals used being provided to regulators and the public has led to a lack of public scrutiny and lack of confidence that the risks of such chemicals are being managed effectively. In terms of information disclosure on which chemicals are being used, the existing EU legislation requires the identified (potential) uses of each REACH-registered substance to be made available to the public (on the European Chemical Agency's (ECHA's) website). Chemical suppliers are required to provide safety data sheets to the users of the chemicals (including unconventional gas companies) on the hazards of the chemicals used and required risk management measures. However, the extent of disclosure of *detailed information* on chemicals used for the fracturing of a given well to authorities and the public is not foreseen under REACH and the Biocides Regulation.

Overview of Possible Measures

The main identified measures to address chemical usage relate to: (a) appropriate assessment and management of the environmental and health risks of the chemicals used; (b) selection of chemicals with lower associated hazards and/or risks to minimise the risks in a given location; (c) disclosure of information on chemicals usage to the authorities and to the public. Different levels of ambition and prescriptiveness of measures to address each of these points are set out in Table 3.3, further detail provided in Appendix D.

[20] The registration deadline for substances manufactured/imported at >1,000 tonnes (and various high-hazard chemicals) was November 2010, with the registration deadline for those at 100-1,000 tonnes being May 2013 and the deadline for all others >1 tonne per year being May 2018.

Quantified estimates of costs have only been derived for a few of the measures and those that have been quantified have relatively low values, once the costs have been apportioned per well pad. The costs that have not been quantified could be much higher, as described below.

Table 3.3 Measures to Address Risks related to Chemicals

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
CHEMICALS – ASSESSMENT									
CAL1	CSA/risk assessment explicitly specific to hydraulic fracturing in the EU to be included in REACH Registration	ML	✓	✓				200	
CAL2	Develop a peer-reviewed EU-level exposure scenario / SpERC for HF for different chemical types	ML	✓	✓	✓			20	
CAL3	CAL2 to be implemented in CSAs for chemicals used in HF and any deviations explained	ML		✓	✓	✓		40	
CAM1	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	MM	✓	✓	✓	✓		300	
CAH1	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	HM	✓	✓	✓	✓		Qualitative Assessment	
CHEMICALS – SELECTION									
CSL1a	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A or 1B	LM		✓	✓			Qualitative Assessment	
CSL1b	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	LM		✓	✓			Qualitative Assessment	
CSL1c	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as aquatic acute category 1 or aquatic chronic category 1	LM		✓	✓			Qualitative Assessment	
CSL1d	Non-use in biocidal products of any substances with [harmonised or notified] classification as aquatic acute category 1 or aquatic chronic category 1	LM		✓	✓			Qualitative Assessment	
CSL2	Non-use of any substances on REACH Candidate List for authorisation (substances of very high concern)	LM	✓	✓	✓			Qualitative Assessment	
CSL3	Negative list of named substances that must not be used in UG extraction (alternative to two measures CSL1 and CSL2)	LM	✓	✓	✓			Qualitative Assessment [4]	
CSL4	Demonstration that all steps practicable have been taken to reduce number, concentration and volume of chemicals used in hydraulic fracturing	ML		✓	✓			Qualitative Assessment	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
CSL5	Authorities to organise an exchange of views/information on environmentally safer technologies and alternatives to the use of chemicals in hydraulic fracturing	LL	✓	✓	✓	✓	✓	Qualitative Assessment	
CSM1a	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	LH		✓	✓			Qualitative Assessment	
CSM1b	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	LH		✓	✓			Qualitative Assessment	
CSM1c	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	LH		✓	✓			Qualitative Assessment	
CSM1d	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	LH		✓	✓			Qualitative Assessment	
CSM2	Positive list of substances expected to be safe under EU UG extraction conditions and require operators to only use substances on this positive list	MM	✓	✓	✓			Qualitative Assessment [4]	
CSM3	Selection of substances (chemicals and proppants) that minimise the need for treatment when present in flowback water	MM	✓	✓	✓			Qualitative Assessment	
CSM4	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.	LM		✓	✓			Qualitative Assessment	
CSH1	Use of water or inert materials only in hydraulic fracturing	HH		✓	✓			Qualitative Assessment	
CSH2a	Non-use of any (non-biocidal) substances with [harmonised or notified] classification for any health or environmental effects	MH		✓	✓			Qualitative Assessment	
CSH2b	Non-use in biocidal products of any substances with [harmonised or notified] classification for any health or environmental effects	MH		✓	✓			Qualitative Assessment	
CHEMICALS – DISCLOSURE									
CDL1	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	ML	✓	✓	✓	✓	✓	Qualitative Assessment	
CDL2	To 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	ML	✓	✓	✓	✓	✓	Qualitative Assessment	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
CDM1	Disclosure of information to Competent Authority: declaration of substance name, CAS number, concentrations, precise 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	HL	✓	✓	✓	✓	✓	Qualitative Assessment	
CDM2	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	HL	✓	✓	✓	✓	✓	Qualitative Assessment	
CDH1	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	HM	✓	✓	✓	✓	✓	Qualitative Assessment	
<u>CHEMICALS – OTHER</u>									
3b x	Monitoring Undertake monitoring of chemicals type and volume used including record keeping	MM		✓	✓	✓		2,000	
N24	Traceability of chemicals used by an operator	LL		✓	✓			Qualitative Assessment	
N26	Select proppants which minimise the HVHF treatment required	MH		✓	✓			Qualitative Assessment	

Notes
1. For key to level of ambition, refer to section 3.1.2.
2. Stage 1: Site identification and preparation. Stage 2: Well design & construction, hydraulic fracturing & well completion. Stage 3: Production (gas extraction and repeat fracturing). Stage 4: Project cessation and well closure. Stage 5: Project post closure and abandonment. For full descriptions refer to section 3.1.2.
3. Costs are in 2012 prices, annualised over 10 years with a discount rate of 4%. For definition of Low and High ambition, refer to Appendix D.
4. Quantified estimates of the costs associated with some elements of these measures have been developed (see Appendix D). However, it was only possible to quantify some of the elements that have low/modest costs. The largest elements of the costs (i.e. impacts on well productivity) could not be quantified for these measures and these will be many times the quantified costs. Therefore no quantitative estimate is presented in this table, in order to avoid misleading the reader.

Economic Impacts – Compliance Costs

Chemicals Assessment

The main compliance costs of ensuring high quality assessments of the risks of chemical usage relate to the technical risk management measures that would need to be implemented. These are very use/site-specific and so cannot be quantified. The costs of undertaking the assessments of risks are considered herein to be administrative costs and are described below.

Chemicals Selection

Chemicals used in fracturing fluids are typically selected to facilitate gas extraction in a cost optimal manner. By way of example, use of gelling agents, which improve proppant placement, has an effect on gas recovery and the literature indicates that not using them could affect gas recovery rates[21].

The most significant costs related to chemicals usage would be dependent on the selection of which chemicals to use in hydraulic fracturing. There are a number of measures in the above table that would seek to influence the choice of which chemicals are used in hydraulic fracturing, with the aim of encouraging or ensuring use of those that pose lower hazards and risks to the environment.

It is of note that the majority of the measures have not been quantified and only a qualitative assessment has been undertaken (see further details in Appendix D). Some of the measures for which it has not been possible to quantify costs could have much higher costs than those that have been quantified here.

Given the large number of different chemical types and diversity of likely geology and other local factors in unconventional gas plays, it is not possible to assess the cost implications quantitatively. However, the measures considered above would progressively reduce the number of substances available to operators. For example, prohibiting use of ‘category 1’ hazard substances (CSL1a-d) would mean that some chemicals which have been used in hydraulic fracturing elsewhere would be unavailable to operators. By also prohibiting the use of ‘category 2’ hazard substances (CSM1a-d), further substances would be unavailable.

Reduced availability of chemical types could have cost implications for operators, including for example costs of increased requirements for maintenance and as a result of higher levels of corrosion (if certain – more technically efficacious – corrosion inhibitors or biocides could not be used).

Furthermore, since many of the chemicals used increase the efficiency of gas extraction[22], reduced availability of chemicals could lead to reduced well productivity and hence reduced income/profit for operators. It has not been possible to quantify these effects for a typical pad as they are thought to vary too much case-by-case. However, the costs of any reduction in gas recovery rates are likely to be far higher than the difference in costs of one chemical compared to another resulting from chemical substitution[23]. By way of example:

---

[21] Data from FracFocus.org suggests that gas recovery may decrease in some cases by 30-50% where fracturing fluids must be gelled. If the properties of fracturing fluids are such that, for example, they are not broken down to sufficiently lower viscosity after fracturing, gas reserves in a well can be reduced by 30%, and initial gas flow rates can be reduced by 80% (Voneiff, Robinson and Holditch, ‘The effects of unbroken fracture fluid on gas well performance’, SPE Production & Facilities, November 1996.

[22] 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 for the European Commission DG Environment, October 2012.

[23] In theory, it would have been possible to quantify the cost resulting from switching one chemical in a fracturing fluid with another (less hazardous) one. However, this is not considered to be the most important cost impact in terms of choice of chemicals used.

- The annualised additional costs of purchasing an alternative chemical for use in fracturing on a typical well pad could be in the order of a few €10s of thousands per year as an annualised cost, per eight well pad[24];

- By contrast, if the choice of chemical had an adverse effect on gas production, the costs could be far higher. If the replacement of this chemical with another led (hypothetically) to even a 0.3-0.4% reduction in gas production rates, this would outweigh the costs of chemical substitution[25].

It is likely that there are some cases where substitution of chemicals could lead to impacts on well productivity that could be much higher than this and even impacts in the order of a few percent would dwarf the costs of alternative chemicals. However, it is also clear that there will be cases where the choice of a lower hazard/risk chemical could be lower cost in terms of chemical price and/or with no adverse effect (or indeed a positive effect on well productivity).

The above discussion is intended to highlight the importance of considering wider cost implications (that cannot be assessed definitively) rather than simply the costs of replacing on or more chemicals with alternatives.

Chemicals Disclosure

No specific compliance costs have been identified related to disclosure of information on usage of chemicals. The main costs are administrative.

Economic Impacts – Administrative Costs to Operators

Chemicals Assessment

The measures identified in relation to assessing and managing the risks of chemicals used go beyond the baseline situation, requiring assessments of chemical safety to be made more specific to use in hydraulic fracturing. A recent investigation[26] of several REACH registration dossiers examined 16 substances that may be used in hydraulic fracturing of shale gas. The review found that that neither hydraulic fracturing or shale gas were explicitly mentioned and that hydraulic fracturing of shale gas reservoirs was not identified as a specific use for any

[24] This assumes 13,500m^3 of water in fracturing fluid, per fracturing. Of this, around 0.5% or around 70 m3 could be comprised of a range of e.g. up to 12 different chemical additives (see Appendix B), with none of them likely to be present individually at more than around 0.1% or around 14m3. Assuming the same density as water and a price for chemicals of €2-5 per kg, the total costs of fracturing fluid chemicals per fracture, per well could be of the order of €130-340,000 (around €17-41,000 annualised over an assumed 10 years before closure or refracturing, using a discount rate of 4%). Eight wells per pad are assumed. If one chemical is substituted (e.g. the most voluminous at 0.1%, in the fracturing fluid), the initial cost of the chemical could be in the order of €30-70,000 per well or €25-65,000 per eight well pad on an annualised basis. Assuming a substance that is twice the price of the one being replaced, the increased costs could be in the order of €25-65,000.

[25] This assumes annual revenues per gas pad of €14 million (see section 4.9 and a €50,000 increase in annualised costs of chemicals purchase per pad.

[26] JRC (2013), Assessment of the use of substances in hydraulic fracturing of shale gas reservoirs under REACH, September 2013.

of the substances, nor was a dedicated exposure scenario (ES) developed by any registrant. However, this review did acknowledge that some of the identified uses may implicitly cover activities related to hydraulic fracturing of shale gas reservoirs. The review includes a number of recommendations in relation to provision of information on use, exposure and risk management for substances used in hydraulic fracturing of shale gas reservoirs.

There would be administrative costs associated with developing a common EU benchmark assessment method for assessing exposure of different chemical types[27]as well as implementing this in assessment of each individual chemical's safety. In measures CAL1, CAL2 and CAL3, operators would need to assess the risks of each chemical used (up to 12 different types of chemicals is assumed, each with a different function) and would also need to explain if their own chemical safety assessment (which could be specific to an individual gas concession/play) differed from the EU exposure scenarios. There would be costs to the operators associated with all of the above, which are over and above the current state of play. For those measures where quantitative estimates have been developed, the costs could be tens or hundreds of thousand Euros per concession[28], depending on the number of different chemicals used and the level of detail of the assessment undertaken. There would also be the costs of fees charged by ECHA when submitting specific 'downstream user' chemical safety assessments (not quantified here).

Other chemicals assessment measures relate to the potential risks of transformation products in the context of fracturing fluids (some of the breakdown products could also pose risks to health and the environment). The costs of these assessments could be substantially higher than for simply assessing the costs of the substances used, because of the increased number of chemicals involved e.g. increasing total administrative costs by a factor of two for an average two transformation products per substance.

Chemicals Selection

The main administrative costs to operators associated with measures to control the selection of which chemicals used would relate to costs of searching for, testing and implementing appropriate alternative chemicals (i.e. research and development costs).

Chemicals Disclosure

The main costs of the measures related to disclosure of information on chemicals use are administrative costs to operators. These have not been quantified but would include the costs of maintaining records (which would be more detailed according to the level of ambition) and information systems to provide the data to the authorities and to the public (e.g. websites). Clearly disclosing simply the names of chemicals used would impose much lower

[27] Exposure scenarios and specific environmental release category (SpERC).

[28] The most significant costs are associated with developing specific 'downstream user' chemical safety assessments under REACH (or equivalent under biocides legislation) for each of the chemicals used, potentially costing in the order of €140-280,000 per concession, for assessments covering several chemicals. A requirement to also look at transformation products and effects of chemical mixtures could cost several multiples of these values. The actual costs could be higher or lower than this range, as it is impossible to accurately predict at this stage how many chemicals would be used and the extent of analysis necessary for each of these.

costs than a requirement to disclose to competent authorities use concentrations, quantities, chemical substance data, dates of fracturing, etc.

The measures regarding disclosure of detailed information per well/concession go beyond the minimum requirements of REACH and other EU chemicals legislation (such as that on biocides).

In terms of disclosure to the public, under REACH, descriptions of uses as well as information on substance properties are usually included on ECHA's database of registered substances and made available per substance. Therefore, measures which include information on chemical use per concession/play/well (measures CDL2 and CDM2) go beyond the existing requirements. Similarly, some of the additional information included in measure CDH1 would not typically be disclosed as part of BAU practices (e.g. date of fracturing, volume and concentration of chemicals used).

In terms of disclosure to competent authorities, detailed information such as that envisaged under measure CDM1 does not explicitly require disclosure under REACH. Member States are responsible for enforcement/inspection under REACH and such enforcement is only required to focus on compliance with REACH itself (though practices may vary between Member States). Therefore, information on, e.g. volume and concentration of chemicals used per well, may not routinely be reported to the competent authorities. It is also noted that the competent authorities for REACH and those for regulation of unconventional gas extraction may be different.

Additional disclosure requirements to the public could potentially impose costs on operators through a loss of confidential business information to competitors.

Economic Impacts – Administrative Costs to Authorities

Chemicals Assessment

There would be costs to the authorities associated with evaluating the suitability of the chemical safety assessments undertaken by industry. However, these costs are assumed to be covered by the fees charged by the authorities for chemicals registrations and approvals/authorisations.

Chemicals Selection

Limiting the chemicals that could be used in hydraulic fracturing would presumably require time to be spent by authorities in developing lists of such chemicals. The measures included here include either a positive list of chemicals that could be used (CSL3), or a negative list of specific chemicals that cannot be used (CSM2). The quantified estimates in the table above are based on assumed time inputs for the authorities in developing those lists (assumed to be around €20-70,000 to set up for both, related to the time inputs required by authorities) and adding new substances to the lists each year (involving more detailed review of data on substances, with potential costs associated with time spent of several hundred thousand Euro per year, depending on the number of substances assessed and level of detail of the assessment). The costs of developing and maintaining a positive list are assumed to be higher than for a negative list, because there would presumably be a greater burden of proof in determining whether substances could be used safely.

Other possible measures to restrict the use of chemicals would impose lower administrative costs on authorities because the criteria used in de-selecting chemicals are already defined, such as through EU chemicals classification legislation (CSL1a-d, CSM1a-d) or existing priority substance lists (CSL2).

Chemicals Disclosure

The main administrative costs to authorities of measures to require disclosure of information would be in processing and, if necessary, disseminating information on chemicals usage from operators. These have not been quantified but are likely to be relatively minimal.

Environmental Benefits

Chemicals Assessment

Without proper assessment of the potential environmental exposure pathways and release levels (e.g. through too-generic safety assessments), the risks of environmental contamination by chemicals used in hydraulic fracturing cannot be effectively managed. The measures considered here would improve the position compared to the baseline, by ensuring that all of the risks specific to chemicals use in HF (potentially at the level of individual concessions) are assessed and then steps taken to manage those risks to an acceptable level. Assessing and managing risks associated with transformation products (CAM1) and/or mixtures (CAH1) would further improve the chances of reducing risks to the environment, though there are scientific challenges with the latter.

Overall, there could be substantial benefits in terms of reduced potential for contamination of water and other environmental media by fully assessing the range of chemicals used in hydraulic fracturing.

Chemicals Selection

The measures related to chemicals selection would limit chemicals that could be used to chemicals of progressively lower *hazard*, depending on the level of ambition. Given the inherent uncertainties associated with environmental exposure pathways underground in particular, reducing the hazard of the chemicals used potentially provides a more certain means of reducing the *risk* to humans and biota through releases of these substances to the environment: if the chemicals are inherently low hazard, even if they are released to the environment the potential for damage is lower than with higher toxicity chemicals. The greater the level of ambition of the measures, the greater the *potential* environmental benefit.

Chemicals Disclosure

The benefits of measures to require disclosure of information on chemicals usage relate to the additional scrutiny of operations. Measures with a greater level of ambition (more information disclosed to authorities or the public) would provide an improved ability to demonstrate liability in the event of environmental contamination (due to more precise location and information on specific chemicals). This additional scrutiny is also likely to provide an incentive to (a) use lower risk chemicals and (b) manage the risks of chemical usage more effectively.

Social Impacts

Measures to require greater levels of chemical safety assessment would presumably lead to some modest/minor increase in requirements for employment, as would measures to require disclosure of information (the latter to a lesser extent than the former). Such measures, along with those requiring use of lower hazard chemicals, would provide social benefits in terms of decreasing the likelihood of health risks.

Measures to require disclosure of information on chemicals usage to the public would improve access to health and environmental protection systems. Consistent rules on disclosure of information across the EU would also help to ensure equality of treatment of individuals in different geographical regions where unconventional gas extraction takes place.

3.5 Water Depletion

Introduction to Risks of Concern

Fracturing requires a significant volume of water: approximately 10,000 to 25,000 m^3 per well (AEAT, 2012). To supply this volume of water, operators typically require either groundwater or surface water. Extraction of groundwater could lower water tables, dewater aquifers and possibly cause changes in water quality (e.g. chemical contamination from mineral exposure to an aerobic environment and bacterial growth due to lower a water table). Extraction of surface water could have impacts on hydrology and hydrodynamics altering the flow regime and water quality. There are potential cumulative effects from a large numbers of operations, particularly in drought and dry periods but also in wet regions where there are stresses within existing water supplies due to substantial demands or limited infrastructure.

Overview of Possible Measures

Possible measures to address the risks of water depletion include (1) improving the understanding of the available water resources and origin and the expected/actual demands for water from the shale gas exploration and production (38a, 38b, 3a vi, 3b vi, 3b ix); and (2) managing the use of water (volume and origin) to minimise the total water use and associated risks of water quality deterioration (38c, 38d, 38e). In terms of implementation, these measures are broadly complementary to each other.

Table 3.4 Measures to Address Risks related to Water Depletion

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
WATER DEPLETION									
38a	Notification of water demand from fracturing operations to relevant water utilities and competent authorities	LM	✓					Qualitative Assessment	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
38b	Demand profile for water	LM		✓				1,600	
N49	Strategic planning and staged approach of play development to avoid peaks in water demand	MM		✓	✓			Qualitative Assessment	
38c	Water management plan	MM		✓	✓			Qualitative Assessment	
3a vi	Site baseline Establish water source availability and test for suitability	MM	✓					6,300	
3b vi	Monitoring Water resources availability	MM		✓	✓			2,400	
3b ix	Monitoring Undertake monitoring of water volumes and origin	MM		✓	✓			2,000	
38d	Reuse of flowback and produced water for fracturing	MM		✓	✓			600	
38e	Use of lower quality water for fracturing (e.g. non-potable ground / surface water, rainwater harvesting, saline aquifers, sea water, treated industrial waterwaters)	MM		✓	✓			Qualitative Assessment	

Notes
1. For key to level of ambition, refer to section 3.1.2.
2. Stage 1: Site identification and preparation. Stage 2: Well design & construction, hydraulic fracturing & well completion. Stage 3: Production (gas extraction and repeat fracturing). Stage 4: Project cessation and well closure. Stage 5: Project post closure and abandonment. For full descriptions refer to section 3.1.2.
3. Costs are in 2012 prices, annualised over 10 years with a discount rate of 4%. For definition of Low and High ambition, refer to Appendix D.

Economic Impacts – Compliance Costs

Compliance costs of 38b (produce demand profile) may vary depending on the complexity of the demand profiling exercise. The measure would include identifying the number of wells, pad locations, drilling sequence, water consumption per unit operation and then establishing flow patterns, i.e. peak and average flow volumes under a variety of scenarios throughout the course of the project.

Compliance costs of 38d (reuse of flowback and produced water for fracturing) would require wastewater characterisation and assessment of suitability for reuse and treatment. The costs would depend largely on the site-specific characteristics of the wastewater and treatment to enable reuse, storage facilities for treated water for reuse, and cost savings from reduced demand for supplied water. The annualised compliance cost is estimated to be €600 per well. This is net of the capital cost of minimal treatment for flowback (i.e. chemical oxidation) at €4,000 to €14,000 per well and cost savings from reduced water demand of approximately €4,000 per well.

Economic Impacts – Administrative Costs to Operators

Administrative costs would be mainly related to information obligations, such as monitoring and reporting of the wastewater generated and treated where water is reused. Administrative costs of baseline survey (3a vi), including locating water sources and identifying availability, water rights, and other issues, would be €6,300 per pad. Annualised monitoring and reporting costs would be €2,400 per pad for water resources availability (3b vi), and

€2,000 per pad for water volumes and origins (3b ix). Cost to operators (in this case expressed as a function of the number of hours) would include preparation of reports and assistance to inspections by public authorities.

Economic Impacts – Administrative Costs to Authorities

Cost to authorities would include reviewing and evaluating monitoring reports and compliance, and are estimated to be less than the cost to operators.

Environmental Benefits

Better understanding of the availability of water in the area, expected/actual demand for water throughout the lifetime of the project site (38a, 38b, 3a vi, 3b vi, 3b ix) and potential impacts on water quality and resources would help operators and authorities to determine an appropriate water management plan (38c). In cases where water reuse is maximised, the risks of water depletion in the area would be reduced.

Social Impacts

The measures are likely to generate additional employment or sustain/safeguard existing employment in water resource management services. Jobs are likely to be created directly, through developing water demand profiles and management plans and their subsequent monitoring, and indirectly support/sustain employment along relevant supply chains. The measures do not directly enhance job quality, but enhance public health due to assuring the availability of water supply. In certain cases the costs imposed by the measures may influence the commercial viability of production at a specific site(s) (i.e. foregone employment). In isolation the measures would appear likely to result in additional employment opportunities. The net effect is unclear and will depend on individual circumstances.

Access to the labour market and to equality of opportunity would not be directly affected by these measures. Beyond the administrative burden associated with the regulation of unconventional gas in general, which is assessed elsewhere, it is unlikely that the measures would result in additional administrative complexity; the measures predominantly require actions by operators. The central social effect would be the protection conferred on public health and availability of water for other activities (industry, agriculture), of which all socio-economic groups and demographics are beneficiaries. In addition, the measures would alleviate the long term cumulative impacts of water scarcity to the society.

3.6 Surface Water Quality

Introduction to Risks of Concern

Measures considered in this section aim to prevent pollution of surface water from leakage and spillage. This may arise from leakage or spillage of flowback and/or produced water *prior* to treatment and disposal, as well as of chemicals, fracturing fluid and mud and stemming from construction activities. Types of pollutants likely to be present in wastewater and indicators of water pollution include VOCs, metals, petroleum hydrocarbons, NORM, oil and grease, BTEX, SVOCs, TDS, pH, sulphates, H_2S, heavy metals, biocides, emulsion breakers and corrosion inhibitors. Salinity of produced water could range from 5,000 to 200,000 ppm (AEAT, 2012). Leakage and spillage could occur during storage (e.g. tank failure) and/or general operation (e.g. pipelines and treatment facilities). There is also risk of pollution due to well failure and induced fractures underground providing pathways to groundwater and subsequently surface water and from improperly treated flowback or produced water leading to pollution of surface water following discharge. Measures related to treatment and disposal of wastewater are discussed in section 3.8 on waste.

Overview of Possible Measures

Possible measures to address risks related to surface water, along with the level of ambition and applicable project stage(s), are described in Table 3.5. All measures aim to mitigate risk by prevention of leaks and spills of flowback/produced water, chemicals, drilling mud, etc. Under these measures, the operator would need to deploy good site management practice, establish baseline conditions and monitor surface water quality and use certain storage equipment and/or runoff control techniques.

In terms of implementation, good site practice measures (33i, 29a, 33a) and site baseline and monitoring measures (3a ii and 3b ii) would be complementary to specific fluid storage and leakage prevention/mitigation measures (29c, 30d, 33b, 33c, 33d, 33e, 33f and 33g). With regard to the individual fluid storage and leakage prevention requirements, implementation of one measure may lead to a reduced need for another. For instance, bunding of fuel tanks (29c) (i.e. a secondary containment) may not be needed if double-skinned tanks (33c) are used. Similarly, requirement of leakage control measures that cover the entire site area, such as a berm around the site boundary (33e) and impervious site liner with puncture proof underlay (33f), may affect (but not completely negate) the need for measures that address storage equipment of various fluids.

Table 3.5 Measures to Address Risks related to Surface Water Quality

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
SURFACE WATER									
33i	Good site security	ML		✓	✓			18,900	
29a	Good practice construction / deconstruction practices, including design for well abandonment	MM		✓		✓		Qualitative Assessment	
33a	Good site practice to prevention of leaks and spills	MM		✓	✓			Qualitative Assessment	
33d	Spill kits available for use	MM		✓	✓			500	
3a ii	Site baseline: Undertake monitoring of surface water body Low Ambition: undertake sampling of surface water body for 3 months	MM	✓					800	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
3a ii	Site baseline: Undertake monitoring of surface water body High Ambition: undertake weekly sampling of surface water body in wet and dry periods over 12 months	MM	✓					3,500	
3b ii	Monitoring: Undertake monitoring of surface water body in wet and dry periods Low Ambition: quarterly sampling	MM		✓	✓	✓		2,000	
3b ii	Monitoring: Undertake monitoring of surface water bodies in wet and dry periods High Ambition: In addition to Low Ambition, include alert system promoting corrective action	MH		✓	✓	✓		2,600	
33e	Berm around site boundary	HM		✓	✓			9,700	
33g	Collection and control of surface runoff	MH		✓	✓	✓		18,100	
29c	Bunding of fuel tanks	HH		✓	✓			1,600	
30d	Use of closed tanks for mud storage	HH		✓				3,300	
33b	Use of tank level alarms	HH		✓	✓			3,100	
33c	Use of double skinned closed storage tanks	HH		✓	✓			6,000	
33f	Impervious site liner under pad with puncture proof underlay	HH		✓	✓			29,600	

Notes
1. For key to level of ambition, refer to section 3.1.2.
2. Stage 1: Site identification and preparation. Stage 2: Well design & construction, hydraulic fracturing & well completion. Stage 3: Production (gas extraction and repeat fracturing). Stage 4: Project cessation and well closure. Stage 5: Project post closure and abandonment. For full descriptions refer to section 3.1.2.
3. Costs are in 2012 prices, annualised over 10 years with a discount rate of 4%. For definition of Low and High ambition, refer to Appendix D.

Economic Impacts – Compliance Costs

Compliance costs for good site management practices (33i, 29a, 33a) would include site security infrastructure (i.e. fencing, alarms, etc. to prevent vandalism and pollution risk) and guards at €18,900, as well as training and awareness programme for construction, management and demolition staff regarding surface water pollution risks and required good site practices.

Annualised compliance costs of specific fluid storage equipment and remedial measures in case of spillage were estimated quantitatively. Construction of a berm (33e) around the site boundary would be approximately €9,700, including the construction material and construction labour. A stormwater drainage system to collect and control surface runoff (33g) would cost approximately €18,100. A puncture proof geo-textile membrane to cover the entire area of a well pad (33f), based on €9.75 per square metre and accounting for 10% unmeasured items, would be approximately €29,600 for a well pad.

In terms of specific requirements on the storage tanks, such as level alarms (33b) and double-skinned tanks (33c), compliance costs vary depending on the number of tanks used, capacity of tanks required and whether these requirements would be applied to all or a selection of fluids handled at the site (e.g. chemicals, fracture fluid, flowback, produced water). The cost for 33c represents the premium for double-skinned tanks rather than single-skinned tanks. It is assumed that tanks are reused up to four times at different pads which influences costs of both 33b and 33c (€3,100 and €6,000 respectively). Costs for tank alarms for all tanks used by operators (33b), includes purchase and installation costs for a simple alarm with a logging feature. Costs of using closed tanks (30d) instead of open tanks for mud storage are estimated at €3,400.

Economic Impacts – Administrative Costs

Administrative costs would be mainly related to information obligations, such as monitoring and reporting of the wastewater generated and treated. The compliance cost of a baseline survey (3a ii) is estimated to be €800 to €3,500 depending on the level of ambition; costs include sampling costs and operator hour costs. These cost estimates assume a baseline survey for one water course and analysis covering suspended solids, BOD, dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic carbons, radioactivity, fracturing chemicals and heavy metals.

Compliance costs for monitoring and reporting (3b ii) would be €2,000 to €2,600 depending on the level of ambition; costs include sampling costs and operator hour costs and for high ambition, the cost of an alert system that would prompt corrective action for relevant parameters identified on a site risk basis. Cost to operators (in this case expressed in number of hours) would include preparation of reports and assistance to inspections by public authorities.

Economic Impacts – Administrative Costs to Authorities

Cost to authorities would include reviewing and evaluating monitoring reports and compliance, and are estimated to be less than the cost to operators.

Environmental Benefits

The measures aim to prevent the risk of surface water pollution by detecting overflow (tank alarms) and using closed rather than open tanks. Some measures aim to reduce the risk of pollution by providing containment (double skinned tanks, bunding, site liner) or having tools for mitigation (e.g. 33d spill kit).

Social Impacts

The measures are likely to generate additional employment or sustain/safeguard existing employment in surface water management services. Jobs are likely to be created directly, through installation and maintenance of additional equipment designed to prevent leakage (e.g. berm around the site boundary, site liner, bunding and/or double skinned tanks, etc.) and their subsequent monitoring, and indirectly support/sustain employment along relevant supply chains. Such requirements would increase demand for specifically qualified construction labour, alongside technical hydrology and engineer support. The measures do not directly enhance job quality, but enhance public health due to avoidance/reduction in water contamination and potential soil contamination. Only in instances where the costs of the measures above affect well viability would they lead directly to any employment loss, although this appears unlikely.

Access to the labour market and to equality of opportunity would not be directly affected by these measures. Beyond the administrative burden associated with the regulation of unconventional gas in general, which is assessed elsewhere, the measures appear unlikely to result in significant additional administrative complexity; the measures predominantly require actions by operators. For instance installation/use of specific equipment and adoption of certain standards. The central social effect is the protection conferred on public health and preserved water quality for other activities (industry, agriculture, recreation, etc.), of which all socio-economic groups and demographics are beneficiaries.

3.7 Air Quality

Introduction to Risks of Concern

Diesel engines (used to provide electricity for drilling and fracturing operations) and vehicles (used on the site and for haulage associated with the site) are required at a significant scale. AEAT (2012) suggests that between 250 and 625 trucks, each with a capacity of 40 m^3 could be needed to manage the flowback from the wells, and an additional 650 truck movements for site construction and drilling over seven months. This would lead to emissions of air pollutants (e.g. CO, NO_x, SO_x and particulate matter (PM)) and greenhouse gases (CO_2, CH_4). In addition, gases released from flowback and produced water may be potentially significant due to the cumulative effect of many wells over long time periods. Similarly, fugitive and/or flared methane and hydrogen sulphides released from the well during drilling and well completion raise concerns in terms of air quality if not controlled.

Overview of Possible Measures

Possible measures to address risks related to air quality, along with the level of ambition and applicable project stage(s), are described in Table 3.6. All measures aim to mitigate the risk by minimising the level of air pollutant emissions from various sources with varying degrees of ambition. Under these measures, the operator would be required to use low-emission equipment (i.e. engines and vehicles), establish baseline conditions and monitor air quality and reduce the level of flares/gas venting. The more specific and comprehensive emission control equipment required, the greater the level of ambition. If operators are required to use a lower-emission power supply rather than diesel engines (16b), measures that aim to reduce emissions from diesel engines (16d) would not be relevant or needed.

Table 3.6 Measures to Address Risks related to Air Quality

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
AIR QUALITY									
59d	Use of vehicles (water, chemicals, waste trucking) that meet minimum air emission standards e.g. EURO standards	LL		✓	✓			Qualitative Assessment	
N54	Encourage industry voluntary approach to reduce air pollutants and greenhouse gases	LM		✓	✓			Qualitative Assessment	
16b i	Low emission power supply: switch to LPG from diesel	LM		✓	✓			48,000	Mutually exclusive with 16d and 16b ii
16b ii	Low emission power supply: switch to grid electricity from diesel	LM		✓	✓			272,200	Mutually exclusive with 16d and 16b i
16d	Application of abatement techniques to minimise emissions (assumed SCR for NO_x and Diesel Particulate Filter (DPF) for PM)	LM		✓	✓			30,400	Mutually exclusive with 16b i and 16b ii
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	MM		✓				2,600	
17c	Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network) High Ambition: In addition to Low Ambition, with no audible or visible flaring	MM		✓				Qualitative Assessment	
3a i	Site baseline Undertake sampling of air quality	MM	✓					700	
3b i	Monitoring Undertake monitoring of air quality	MM		✓	✓			5,800	
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	MH		✓	✓			3,800	
17b	Reduced emission completions to eliminate gas venting: prohibit venting of gas; capture and cleaning for use of gas released from fracture fluid and produced water	HH		✓	✓			- 28,300	

Notes
1. For key to level of ambition, refer to section 3.1.2.
2. Stage 1: Site identification and preparation. Stage 2: Well design & construction, hydraulic fracturing & well completion. Stage 3: Production (gas extraction and repeat fracturing). Stage 4: Project cessation and well closure. Stage 5: Project post closure and abandonment. For full descriptions refer to section 3.1.2.
3. Costs are in 2012 prices, annualised over 10 years with a discount rate of 4%. For definition of Low and High ambition, refer to Appendix D.

Economic Impacts – Compliance Costs

Compliance costs for low emission power supply by switching to LPG (16b i) are estimated at €48,000; it is assumed that there are zero capital cost as the service is contracted i.e. the operator could choose supplier with engines fuelled by LPG. Compliance costs for low emission power supply by switching to grid electricity (16b ii) are estimated at €272,200; the cost includes grid connection costs assuming 1km length, 3-core 120mm cable and the difference in running costs (fuel/electricity) and furthermore, it is assumed that any differences would be reflected in the costs incurred by the operator and that infrastructure for connection to grid is readily available (if not then costs are an underestimate).

If diesel generators were used by operators, specific air pollutant abatement techniques, such as diesel particulate filters (DPF) and selective catalytic reduction (SCR), could be used to reduce PM and NO_x, respectively (16d). Compliance cost is estimated at €30,400, based on an average engine size for drilling rig and well injection of 300kW and 16 engines are used at any one time. Costs have been estimated by dividing total costs for DPFs and SCR according to the number of wells/pads that could be drilled over an eight year lifetime. Whilst operators are likely to contract generating equipment, it is reasonable to assume that a contractor who has retrofitted engines and incurred these costs would pass them through to the operator.

Requiring flares or incinerators to reduce emissions from fracturing fluid at exploration stage (17c) would include combustion completion devices, the cost of which is €2,600. Measure 17b, reduced emission completions (REC), also referred to as ‘green’ or ‘flareless’ completions, use specially designed equipment at the well site to capture and treat gas so it can be directed to the sales line. Compliance costs, estimated based on incremental REC contracted service rather than purchase of equipment, are negative: because of the savings based on gas and condensate recovered per REC event, cost savings would be approximately €28,300.

Preparing an emissions reduction plan (16a), including an assessment of potential local air quality impacts and compliance with ambient air quality limit values, is estimated at €3,800. This compliance cost includes developing an emissions inventory for the site, undertaking dispersion modelling of the inventory to estimate concentrations within site boundaries and surrounding areas, undertaking additional modelling on nearby population and/or sensitive habitats and identifying options for reducing emissions.

Economic Impacts – Administrative Costs to Operators

Administrative costs would be mainly related to information obligations, such as monitoring and reporting of the air quality and emissions data. Compliance costs of a baseline survey (3a i) would be €700, assuming monitoring for combustion gasses (NOx, NO_2, PM_{10}, SO_2, CO and VOCs) for three months and using passive monitoring techniques at circa six points in the vicinity of a pad. Compliance costs for monitoring and reporting (3b i) are €5,800. Costs to operators include preparation of reports and assistance to inspection by public authorities, and the costs would vary depending on the frequency of the reporting requirements.

Economic Impacts – Administrative Costs to Authorities

Cost to authorities would include reviewing and evaluating monitoring reports and compliance, and are estimated to be less than the cost to operators, on average.

Environmental Benefits

If lower emission power supply (16b) is applied, on-site emissions would be reduced (in case of LPG) or removed entirely (grid power supply). Assuming diesel engines are used and emission reduction techniques are in place, there would be reduction of various air pollutants, including:

- 16d: DPF would reduce PM by 95% and SCR would reduce NOx by 85%;
- 17b: REC would reduce 129 tonnes of methane, 19 tonnes of VOCs and 1.4 tonnes of hazardous air pollutants per well; and
- 17b: REC would lead to higher reductions than measure 17c, the second of which addresses emissions from fracturing fluid (flowback) only through flaring rather than elimination of emissions.

Social Impacts

The measures are likely to generate additional employment or sustain/safeguard existing employment related to industrial emissions management services. Jobs are likely to be created directly, through installation and maintenance of additional equipment designed to reduce emissions and their subsequent monitoring, and indirectly support/sustain employment along relevant supply chains. Such requirements would increase demand for specifically qualified construction labour, alongside engineering support. The measures do not directly enhance job quality, but enhance public health due to avoidance/reduction in air pollution. Only in instances where the costs of the measures above affect well viability would they lead directly to any employment loss, although this appears unlikely.

Access to the labour market and to equality of opportunity would not be directly affected by these measures. Beyond the administrative burden associated with the regulation of unconventional gas in general, which is assessed elsewhere, it appears unlikely that the measures would result in significant additional administrative complexity; the measures predominantly require actions by operators (for instance 59d and 16b i and ii). The central social effect is the protection conferred on public health.

3.8 Waste

Introduction to Risks of Concern

Well drilling, hydraulic fracturing, production of unconventional gas and well plugging/testing generate a significant volume of waste, in particular in the form of flowback, produced water and drilling mud. For the purposes of the illustrative concession (see Appendix B), approximately 13,500 m^3 of water is assumed to be used per well per fracture, 50% flowback is achieved out of the total volume of fracturing fluid used per fracture and

35% of the total volume of fracture fluid used per fracture is recycled. Furthermore, proppant and additives would be 2,800 tonnes and 75m^3 respectively per fracture. Types of pollutants likely to be present in wastewater and indicators of water pollution include VOCs, metals, petroleum hydrocarbons, NORM, oil and grease, BTEX, SVOCs, TDS, pH, sulphates, H_2S, heavy metals, biocides, emulsion breakers and corrosion inhibitors. Salinity of produced water may range from 5,000 to 200,000 ppm (AEAT, 2012). Measures considered in this section aim to ensure the appropriate management, treatment and discharge of wastes, in particular wastewaters and drilling mud.

Overview of Possible Measures

Possible measures to address risks related to waste, along with the level of ambition and applicable project stage(s), are described in Table 3.7. All measures (except 27 c i and ii) aim to mitigate the risk by proper management, treatment and disposal of wastewater. Under these measures, the operator would need to characterise wastewaters and determine and undertake, in conjunction with wastewater treatment service providers, the appropriate treatment and/or suitability of treatment plant to properly treat wastewater to the required discharge standards.

Under measure 27c i (allow injection of untreated flowback and produced water into designated formations for disposal, provided specific conditions are in place), flowback and produced water would not be treated before injection into geological formations and therefore implementation of this measure conflicts with measures 36c (regarding establishing treatment requirements) and N52 (a ban on injection of wastewaters). On the other hand, measure 27c ii (injection of treated flowback and produced water into designated formations for disposal, provided specific conditions are in place) would require the wastewater to be treated, could be implemented alongside 36c but remains conflicting with 27c i and N52. Monitoring and reporting measures (3b xiii, xiv and xv) would be compatible with other waste treatment/disposal measures.

It may not be possible to confirm the costs and benefits of some options (e.g. 27c i and 27c ii regarding injection) until the scale of wastewater disposal requirements are established.

Table 3.7 Measures to Address Risks related to Waste

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
WASTE									
N47	Operator demonstrates availability of appropriate wastewater treatment facilities	LL	✓	✓	✓			Qualitative Assessment	
36c	Treatment requirements for wastewater and capability of treatment works to treat wastewater established	LL		✓	✓			Qualitative Assessment	
27c ii	Allow injection of flowback and produced water into designated formations for disposal[4], provided specific conditions are in place ii) untreated wastewater	LL		✓	✓			Qualitative Assessment	Mutually exclusive with 27 c i, 36c and N52
N50	Lined open ponds with safety net protecting biodiversity	ML		✓	✓			Qualitative Assessment	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
27c i	Allow injection of flowback and produced water into designated formations for disposal[4], provided specific conditions are in place i) treated waste water	MM		✓	✓			Qualitative Assessment	Mutually exclusive with 27 c ii and N52
3b xiii	Monitoring Undertake monitoring of drilling mud volumes and treatment	MM		✓	✓			2,300	
3b xiv	Monitoring Undertake monitoring of flowback water return rate and characterise	MM		✓	✓			11,000	
3b xv	Monitoring Undertake monitoring (volume and characterisation) of produced water volume and treatment solution	MM		✓	✓			47,000	
N53	Consider wastewaters from unconventional gas operations as hazardous waste	MM		✓	✓			Qualitative Assessment	
N51	Consider wastewaters hazardous unless operator demonstrates otherwise	MH		✓				Qualitative Assessment	
N52	Ban injection of wastewaters into geological formations for disposal[4]	MH		✓	✓			Qualitative Assessment	
30c	Use of closed loop system to contain drilling mud	HH		✓	✓			19,700	

Notes
1. For key to level of ambition, refer to section 3.1.2.
2. Stage 1: Site identification and preparation. Stage 2: Well design & construction, hydraulic fracturing & well completion. Stage 3: Production (gas extraction and repeat fracturing). Stage 4: Project cessation and well closure. Stage 5: Project post closure and abandonment. For full descriptions refer to section 3.1.2.
3. Costs are in 2012 prices, annualised over 10 years with a discount rate of 4%. For definition of Low and High ambition, refer to Appendix D.
4. It is to be noted that under current EU legislation, direct discharges of pollutants into groundwater are prohibited under the Water Framework Directive (2000/60/EC) and the Mining Waste Directive (2006/21/EC) applies to the management of extractive waste whether at the surface or in the underground.

Economic Impacts – Compliance Costs

Compliance costs of these measures would be related to: (1) characterisation/classification of wastewater and identification of required treatment and/or suitability of treatment available; (2) treatment; (3) disposal of wastewater by injection into geological formations under specific conditions; and (4) storage and transportation of wastewater and treated water associated with treatment and disposal. For injection of treated or untreated wastewater for disposal under specific conditions (27c), additional costs to ensure safe disposal might be incurred.

Closed loop systems for managing drilling mud (30c) employ a suite of solids control equipments to minimise drilling fluid dilution and provide more efficient handling of the drilling wastes. The system can include a series of linear motion shakers, mud cleaners and centrifuges followed by a dewatering system. The cost of a closed loop system is estimated to be approximately €19,700. As a closed loop system would reduce the amount of mud to be stored, fewer closed tanks (between 25% and 50%) may be required for closed loop drilling.

Economic Impacts – Administrative Costs to Operators

Administrative costs would be mainly related to information obligations, such as monitoring and reporting of the wastewater generated and treated. Administrative costs of monitoring and reporting measures are estimated as follows:

- Drilling mud (3b xiii): €2,300, assuming two mud/cutting samples, during the course of drilling or once drilling is complete, and operator hours for analysis and reporting;
- Flowback water (3b xiv): €11,000, assuming weekly sampling for a two month fracturing operation and operator hours for analysis and reporting. Analysis is assumed to cover oil and grease, BTEX, VOCs, SVOCs, TDS, pH, sulphates, H_2S, heavy metals, NORM, biocides, emulsion breakers and corrosion inhibitors; and
- Produced water (3b xv): €47,000 for weekly sampling for a single year and operator hours for analysis and reporting. Analysis coverage is assumed to be the same as for flowback water (3b xiv), and monitoring and reporting to be conducted during production years.

Cost to operators (in this case expressed in number of hours) would include preparation of reports and assistance to inspections by public authorities.

Cost to authorities would include reviewing and evaluating monitoring reports and compliance, and are estimated to be less than the cost to operators.

Economic Impacts – Administrative Costs to Authorities

Measure 27c would involve a permitting regime subject to specific risk characterisation, assessment and management requirements, which would lead to administrative costs for authorities related to staff time to develop and administer a permitting system and providing technical support.

Environmental Benefits

The main environmental benefit would be reduced risks of improperly treated flowback or produced water leading to pollution of ground and surface water and hence usable water resources. The more ambitious the measures, the greater likelihood that the pollutants would be removed from wastewater. A closed loop system to manage drilling mud has an additional benefit of reduced amount of mud and waste volume, which subsequently reduces the overall risk of surface water pollution. In addition, implementation of monitoring and reporting measures would allow actions to be taken to manage issues associated with waste.

Social Impacts

The measures are likely to generate additional employment or sustain/safeguard existing employment in wastewater treatment and disposal services. Jobs are likely to be created directly, through installation and maintenance of these systems and their subsequent monitoring, and indirectly support/sustain employment along relevant supply chains. Such requirements would increase demand for specifically qualified construction labour, alongside technical wastewater/hydrology and engineering support. The measures do not directly enhance job quality, but enhance public health due to avoidance/reduction in water contamination and potential soil contamination. It is not clear whether the measures, in isolation, would lead directly to any employment loss.

Whilst the capital requirements incurred by businesses for wastewater treatment may influence decisions on individual well viability, it appears likely that such influences would be marginal, with the likely exception of offsite wastewater treatment plants, where the costs are substantial. Such a requirement may tend to increase the geographical concentration of well pads in areas where infrastructure exists or of those in proximity to any new infrastructure with associated piping and transport movements and such effects would need to be considered on a site by site basis. This concentration may result in additional social impacts, arising from operations at greater density, where these were in proximity to people, or social amenities, although this is likely to be limited.

Access to the labour market and to equality of opportunity are not directly affected by these measures and would depend on job training and recruitment schemes carried out by construction and technical firms and any service providers. Beyond the administrative burden associated with the regulation of unconventional gas in general, which is assessed elsewhere, it is not clear that the measures would result in additional administrative complexity; the measures predominantly require actions by operators. The central social effect is the protection conferred on public health.

3.9 Post-Closure

Introduction to Risks of Concern

Following the closure of unconventional gas wells, there is a concern that there could be longer-term impacts on the environment through impacts arising a long period after active gas extraction. For example, the long timescales with which groundwater takes to flow in some cases means that contaminants introduced could potentially only appear in potable (or other) water supplies some time after closure. Similarly, geological or seismic events after well closure could potentially lead to new exposure pathways underground for contaminants that remain underground following hydraulic fracturing. There is thus the potential for contamination of ground and surface water. There is also the potential for gas to escape following well closure due to well failure, leading to safety and environmental risks.

Furthermore, without appropriate monitoring and liability regimes, there exists the potential that the costs of addressing any such risks may not be borne by the operator.

Overview of Possible Measures

The main measures to address risks post-closure broadly fall into the following categories:

- Abandonment surveys for various parameters, with varying levels of ambition in terms of control of risks. These surveys could cover a wide range of different parameters and are important for establishing the condition of the site upon abandonment by the operator;

- Post closure inspections and maintenance. These could help to ensure that any environmental releases are identified in a timely manner and the risks appropriately managed to minimise harm to people or the environment; and

- Requirements for retention of ownership and liability for damage, transfer of responsibilities and financial guarantees/contributions from operators to cover the costs of monitoring and remedial action. Given the potential long-term nature of the pollutant release pathways (for example), it is likely to be important to retain appropriate provisions for liability over several years following well closure.

Table 3.8 Measures to Address Risks Post-closure

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
POST CLOSURE									
N22	Maintain records of well location and depth indefinitely	LL				✓	✓	Qualitative Assessment	
13d vi	Abandonment survey: Undertake survey of biodiversity, ecology and invasive species survey	LL					✓	4,900	
13d viii	Abandonment survey: Undertake assessment of land use, infrastructure and buildings (Low Ambition: desk study)	LL					✓	400	
13d ix	Abandonment survey: Undertake assessment of ex-anti underground wells and structures (Low Ambition: desk study)	LL					✓	300	
N11	Operator to provide financial guarantee[4] to competent authority to cover costs of any remedial action following transfer of responsibility	LM					✓	Qualitative Assessment	
N12	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]	ML					✓	Qualitative Assessment	
26g	Implementation of remedial measures if well failure occurs	MM		✓	✓	✓	✓	Qualitative Assessment	
29a	Good practice construction / deconstruction practices, including design for well abandonment	MM					✓	Qualitative Assessment	
N10	Operator remains 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]	MM				✓	✓	Qualitative Assessment	
13d ii	Abandonment survey: Undertake sampling of surface water bodies near the pad	MM					✓	1,600	
13d iii	Abandonment survey: Undertake sampling of groundwater near the pad	MM					✓	1,000	
13d iv	Abandonment survey: Obtain data on drinking water abstraction points (wells, boreholes, springs, surface water abstraction points)	MM					✓	800	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
13d v	Abandonment survey: Undertake land condition (soil) survey around pad	MM					✓	2,000	
13d vii	Abandonment survey: Undertake sampling for methane near surface in the pad location	MM					✓	Qualitative Assessment	
13d viii	Abandonment survey: Undertake assessment of land use, infrastructure and buildings (High Ambition: desk study and aerial survey)	MM					✓	800	
13d ix	Abandonment survey: Undertake assessment of ex-anti underground wells and structures (High Ambition: desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells)	MM					✓	600	
13b i	Specific post closure well inspection, maintenance and monitoring[5]/reporting programme (i) following detection of possible pollution (low ambition)	LH					✓	Qualitative Assessment	
12	Specific post closure risk assessment, well plugging, inspection and monitoring[5] requirements (e.g. for releases to air, well integrity, periodicity of inspections, wellhead monitoring every 90 days)	HH				✓		50,900	
13b ii	Specific post closure well inspection, maintenance and monitoring[5]/reporting programme (ii) periodic inspection and monitoring (high ambition)	HH					✓	Qualitative Assessment	
13c	Ownership and liability of wells transferred to a competent authority on surrender of the site licence[6] following a period of monitoring	HH					✓	Qualitative Assessment	

Notes
1. For key to level of ambition, refer to section 3.1.2.
2. Stage 1: Site identification and preparation. Stage 2: Well design & construction, hydraulic fracturing & well completion. Stage 3: Production (gas extraction and repeat fracturing). Stage 4: Project cessation and well closure. Stage 5: Project post closure and abandonment. For full descriptions refer to section 3.1.2.
3. Costs are in 2012 prices, annualised over 10 years with a discount rate of 4%. For definition of Low and High ambition, refer to Appendix D.
4. It is to be noted that a financial guarantee is required prior to the commencement of any operation involving the accumulation or deposit of extractive waste in a waste facility (which encompasses underground structures) under the Mining Waste Directive (2006/21/EC).
5. The Mining Waste Directive (2006/21/EC) stipulates that operators of a waste facility (which encompasses underground structures designated for the accumulation or deposit of extractive waste) are responsible for the maintenance, monitoring, control and corrective measures in the after closure phase for as long as may be required by the competent authority, taking into account the nature and duration of the hazard.
6. Transferring ownership and liability to a competent authority on surrender ensures that explicit tenure and legal responsibility beyond normal practice is maintained regarding environmental risk management following relinquishment by the operator.

Economic Impacts – Compliance Costs

The largest quantified annualised compliance costs relate to well plugging and associated inspections (measure 12) at an estimated €50,900 per well. This measure also includes elements of administrative costs (related to monitoring), although these are not separated out in the table above.

However, the most significant costs associated with the identified measures are likely to be those relating to (measure N12) provision of financial contributions to the authorities to cover ongoing monitoring and related activities and (measure N10) a retained responsibility for monitoring, reporting and corrective measures following well closure and also prior to transfer of responsibility to competent authority, both of which are assumed to be required for a minimum of 20 years[29]. There would also be a cost associated with provision of financial guarantees to cover remedial action (N11) following abandonment and transfer of ownership and liability to the authority (13c).

The costs of implementing any remedial measures if well failure were to occur (26g) could also be significant, but this is entirely dependent on the nature and scale of potential failure.

Economic Impacts – Administrative Costs to Operators

Many of the quantified costs related to post-closure are considered herein to be administrative costs and relate to the costs of abandonment surveys. In total, the annualised cost is estimated at €10,200 to €10,900 per pad. The most significant aspect of this cost being the costs for survey of biodiversity, ecology and invasive species (13d vi). Costs associated with monitoring of land use, infrastructure and buildings (13d viii) would be higher if an aerial survey is undertaken. Similarly, costs for assessment of underground wells and structures in place prior to unconventional gas activities would be higher if additional checks are made on the integrity of construction, for example.

Economic Impacts – Administrative Costs to Authorities

Administrative costs to authorities are those related to monitoring and inspection following well abandonment and transfer of liability from the operators, which is assumed to be required for a period of 20-30 years. It is assumed that these costs would be covered by financial contribution from the operator.

There would also be costs associated with maintaining records of well location and depth, as well as administering any financial guarantee system.

Environmental Benefits

The main environmental benefits arising from the measures set out above would be related to reduced risk of contamination of surface and groundwater in particular, through appropriate well plugging, etc. of wells together with facilitating timely action to address any adverse environmental impacts that are identified through ongoing monitoring. The intention of these measures is to aim for assurance that, upon abandonment, surface water, groundwater, drinking water and land quality are comparable to the baseline conditions established pre-development.

A clear responsibility/liability regime extending beyond that set out in the MWD to the full scale of unconventional gas activities and following licence surrender through 13c (transfer of responsibilities and liability linked to the wells following closure and reinstatement) would help to ensure that the environmental risks continue to be avoided into the future.

---

[29] 20 years has been assumed based on a similar requirement stated in the CCSD Article 18 regarding transfer of responsibility. The MWD does not provide for a specific timeframe.

Social Impacts

In addition to a (modest) positive impact on employment that would be achieved through undertaking the required monitoring, for example, there would be inter-generational benefits in terms of equality of environmental protection and public health/safety through ensuring that people are protected in the future as well as during the lifetime of the unconventional gas extraction activities.

3.10 Public Acceptance

Introduction to Risks of Concern

Unconventional gas developments have, in certain instances, caused significant public concern and protest. Public concern may be motivated by a range of issues, from opposition to unconventional gas wherever it occurs; concern over environmental damage; to localised concerns over property values, livelihoods; health and safety implications and noise and other disturbance. The measures in this section address public acceptability and/or engagement. They provide outlets for public concerns to be communicated and redressed. They require operators to make public the results of baseline and monitoring surveys; the conditions of operators' environmental permits and develop understanding and management of the risks posed by unconventional gas extraction.

Overview of Possible Measures

The measures are set out in Table 3.9, along with their level of ambition and applicable project stage. Fuller information on individual measures, information sources and assumptions is provided in Appendix D. The remainder of the section explores the costs and benefits associated with the measures.

The measures require operators to make public the results of baseline and monitoring surveys; well integrity tests; resource use and any environmental or safety incidents. They require competent authorities to publish information on the conditions attached to operator environmental permits and details of the location and extent of unconventional gas activities (including details of abandoned wells). Competent authorities would also be required to publish analysis of the costs benefits and risk of unconventional gas to facilitate public awareness. The measures mandate operators to conduct public consultation at regular stages and preclude the use of non-disclosure agreements.

Table 3.9 Measures to Address Risks related to Public Acceptance

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
Public Acceptance									
N23	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	LL		✓	✓	✓	✓	Qualitative Assessment	
15 ii	Public consultation and engagement by operators: (ii) for permitting	LL	✓	✓			✓	1,400	
N41	Member State Competent Authorities provide information on the licences and permits of operators involved in unconventional gas exploration and production	LL	✓	✓	✓	✓	✓	30	
N42	Prohibit non-disclosure agreements between local residents and/or landowners and unconventional gas operators	LL	✓	✓	✓	✓	✓	Qualitative Assessment	
N40	Member State Competent Authorities provide a map of planned and existing exploration, production and abandoned well locations	MM		✓	✓	✓	✓	20	
15 i	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment)	MM	✓	✓	✓	✓	✓	5,900	
N03	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	MM	✓	✓	✓	✓	✓	Qualitative Assessment	
N04	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	MM	✓	✓	✓	✓	✓	Qualitative Assessment	

Notes
1. For key to level of ambition, refer to section 3.1.2.
2. Stage 1: Site identification and preparation. Stage 2: Well design & construction, hydraulic fracturing & well completion. Stage 3: Production (gas extraction and repeat fracturing). Stage 4: Project cessation and well closure. Stage 5: Project post closure and abandonment. For full descriptions refer to section 3.1.2.
3. Costs are in 2012 prices, annualised over 10 years with a discount rate of 4%. For definition of Low and High ambition, refer to Appendix D.

Economic Impacts – Compliance Costs

- **Public consultation and engagement by operators (15 ii)** requires public engagement as per permit requirements and includes the labour costs to deliver various activities related to permitting (website publication, provision of information and public meetings). This is estimated at some €1,400. **15 i** extends the consultation to early stage consultation (at initial exploration, pre-site development and pre-permitting stages[30]) and requires information to be published on websites and information

[30] It is to be noted that should there be a mandatory EIA (see measures in 3.11), this would include public consultation.

prepared and presented at public meetings. Costs (that include ongoing consultation during the production stage) are estimated at some €5,900; and

- **N23 is the 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**. Costs are likely to be borne in the collation of this information. Enhanced public scrutiny may also result in improved industry practice, which may too incur further cost.

Economic Impacts – Administrative Costs to Operators

Whilst there are compliance costs associated with the measures, administration costs borne by operators are expected to be negligible.

Economic Impacts – Administrative Costs to Authorities

- **N41 is Member State Competent Authorities to provide information on the licences and permits of operators involved in unconventional gas exploration and production**. Annualised cost for the Competent Authority to draw this information together from all well applications and publish the relevant details on a website is assessed to be negligible at some €30. **Member State Competent Authorities providing a map of planned and existing exploration, production and abandoned well locations (N40)** is estimated at a similar level; some €20, assuming these are updated and published annually;

- **N03 is 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**. The Member State would be required to collate and catalogue the information on a data repository and respond to requests for information from the public. Negligible costs to operators are assumed as they would have to prepare permit applications in any case. **The regular publication by EU institutions and/or Member States of peer reviewed information to the public on the current state of knowledge of potential environmental risks and benefits from unconventional gas as well as risk management is set out in N04**. This would involve establishing and maintaining a website with this information; and the collation of research and emerging information; and

- **N42 prohibits the use of non-disclosure agreements** between local residents and/or landowners and unconventional gas operators. These may, for example, prevent landowners from making public details of operations or potential operations, including their experiences of operations that might affect property prices, insurance availability or ability of mortgages to be secured on properties. The measure does not impose costs per se and the economic effects could include avoidance of damage and loss of asset values. They may also result in foregone revenue from operators.

Environmental Benefits

By requiring detailed testing and monitoring results to be published, the measures would indirectly serve to limit the environmental consequences of businesses. Potentially, the likelihood and scale of environmental risks may also be reduced.

Social Impacts

The measures aim to keep the public informed, both of specific activities and technical knowledge on the costs, benefits and risks of unconventional gas extraction, more generally. The measures could be considered to protect the social autonomy of local communities; advance good governance and enable public participation and access to justice.

3.11 Other Measures

Introduction to Risks of Concern

This section considers risk management measures not categorised elsewhere. The measures are subdivided given the nature and number of measures. First, additional site survey conditions related to surface conditions. Second, those related to emergency response, including contingency planning and risk assessment. Third, measures related to assurance and project delivery; these include Competent Authority inspections and environmental accreditations and actions required by operators for regulatory compliance. Fourth, additional monitoring including emissions and energy use both at individual sites and of the concession or gas play area as a whole. Fifth, noise management and mitigation. Sixth, measures associated with environmental permitting and assessment, including Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA). And seventh measures associated with transportation and the use of surface pipes to move water and wastewater.

Drilling activities typically last for up to one month, with the number of drilling days dependent on whether the wells are vertical (27 days) or horizontal (25 days)[31]. Indicatively, some 135 truck movement are anticipated, associated with well pad construction and some 515 with well drilling.[32] Clearly these would differ on a site by site basis.

Overview of Possible Measures

The measures under each category are set out in Table 3.10, along with their level of ambition, applicable project stage and whether they have been assessed qualitatively or quantitatively. Fuller information on individual measures, information sources and assumptions is provided in Appendix D. The remainder of the section explores the costs and benefits associated with the measures. They are:

i) **Site surface conditions surveys:** comprising baseline surveys ascertaining drinking water abstraction points, nearby land uses/infrastructure;

ii) **Incident response:** measures include monitoring activities (related to incident occurrence and response); ongoing assessment of major hazards; the development of emergency response plans in the event of

---

[31] Depth of well divided by drilling length per day. See Appendix B.

[32] DG ENV (2012) Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe. AEAT

underground leaks, contamination or spillages; notification of incidents, including making details available to the public; and ongoing contingency planning;

iii) **Assurance and delivery:** a series of measures related to the activities of Competent Authorities or those required by the operator to comply with regulation. It includes consideration of the interaction between chemicals used and equipment; the use of non toxic drilling muds; establishing and maintaining environmental management system (EMS) accreditation; assessments of the technical and financial capabilities/position of operators, including guarantees for civil and environmental liability; and the development of additional technical guidance for assessing environmental effects from unconventional gas activity. Measures are also included related to inspection requirements, including retaining sufficient inspection capacity within Competent Authorities, alongside independent inspections, where required. Furthermore, measures are included regarding the use of approved/non toxic drilling muds and site reinstatement plan development;

iv) **Monitoring studies/surveys:** ongoing surveys related to drinking water abstraction, soil, energy use and greenhouse gas emissions; including strategic monitoring of the overall gas play to be undertaken by Member States;

v) **Noise management and mitigation:** includes baseline and monitoring studies to ascertain existing noise levels and impact of hydraulic fracturing activity. Measures relate to specifying operational hours; noise screening; designated routes and machinery orientation to minimise noise;

vi) **Environmental permitting and assessment:** measures related to ongoing independent assessment of the adequacy of environmental management measures; those requiring operators to be subject to a national permit from the Competent Authority; and mandatory SEA and EIA, including assessments of cumulative effects. A number of measures require strategic planning from public authorities, the development of integrated permitting across Member States for unconventional gas, and the preparation of an underground regional impact assessment to facilitate long-term planning of underground resource exploration and production;

vii) **Transport (including temporary surface pipes):** baseline establishment and monitoring studies of traffic volumes and patterns; traffic impact assessment (which also includes noise and emission aspects); transport, water and waste management plans; and consideration of site location to minimise haulage requirements. Three measures relate to the use of temporary surface pipes to aid water collection and distribution and aim to minimise vehicle movements.

Table 3.10 Measures to Address Other Risks

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
OTHER MEASURES									
i)	***Site Surface Conditions***								
3a iv	Site baseline Obtain data on drinking water abstraction points (wells, boreholes and springs)	MM	✓					1,200	
3a v	Site baseline Undertake land condition (soil) survey around pad	MM	✓					1,700	
3a xii	Site baseline Undertake assessment of land use, infrastructure and buildings. Low ambition – desk study	MM	✓					200	
3a xii	Site baseline Undertake assessment of land use, infrastructure and buildings. High ambition – desk and aerial survey	MM	✓					500	
ii)	***Incident Response***								
N25	Reversal of the burden of proof for unconventional gas operators in the context of liability in case of environmental damage	LL		✓	✓			Qualitative Assessment	
N38	Maintain operator liability for any pollution arising from wells for a period of 100 years	LM					✓	Qualitative Assessment	
N39	Maintain operator liability for any pollution arising from wells indefinitely	LM					✓	Qualitative Assessment	
N08a	In the case of an incident/accident significantly affecting the environment: a) operator informs competent authority immediately	ML		✓	✓	✓		Qualitative Assessment	
N08b	In the case of an incident/accident significantly affecting the environment: 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	ML		✓	✓	✓		Qualitative Assessment	
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)	MM	✓	✓	✓			9,900	
3b xix	Monitoring: Undertake monitoring of spills volume, nature, location and clean-up (including reporting)	MM		✓	✓	✓		2,000	
9b	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	HM		✓	✓	✓		Qualitative Assessment	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
9a	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	HH	✓	✓	✓	✓		Qualitative Assessment	
iii)	***Monitoring (not elsewhere classified)***								
N27	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	MM	✓	✓	✓	✓	✓	60	
3b iv	Monitoring Undertake monitoring of drinking water abstraction points (wells, boreholes, springs, surface water)	MM		✓	✓	✓		2,400	
3b v	Monitoring Undertake land condition (soil) tests every five years outside site boundary	MM		✓	✓	✓		400	
3b xi	Monitoring Undertake monitoring of energy source and use	MM		✓	✓	✓		2,000	
3b xii	Monitoring Undertake monitoring of greenhouse gas emissions	MM		✓	✓	✓		2,000	
iv)	***Assurance and Delivery***								
N36	Operators work together to ensure efficient provision of gas collection and wastewater treatment infrastructure	LM	✓	✓	✓			Qualitative Assessment	
N28	Assessment by the Competent Authority of the technical and financial capacity of an operator	LM	✓	✓			✓	Qualitative Assessment	
N29	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)	LM	✓	✓	✓	✓	✓	Qualitative Assessment	
N21	Implement precautions to prevent invasive species by cleaning vehicles	ML		✓	✓			Qualitative Assessment	
N37	Pad construction activities staged to reduce soil erosion and to coincide with low rainfall periods	MM	✓	✓				Qualitative Assessment	
3a ix	Site baseline Undertake survey of biodiversity and ecology survey	MM	✓					6,500	
3b xvi	Monitoring Undertake periodic surveys of biodiversity, ecology and invasive species	MM		✓	✓	✓		900	
N18	Ensure equipment is compatible with composition of fracturing chemicals	MM		✓	✓			Qualitative Assessment	
N19	Carry out thorough planning and testing of equipment prior to hydraulic fracturing operations	MM		✓	✓			Qualitative Assessment	
N30	The European Commission to develop further criteria/guidance for the assessment of environmental impacts from unconventional gas	MM	✓	✓	✓	✓	✓	20	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
N31	Inspections by Competent Authorities during all stages of development (e.g. of well completion reports and environmental risk management and controls)	MM		✓	✓	✓	✓	10	
N33	Independent inspection during all stages of development of well integrity	MM		✓	✓	✓	✓	Qualitative Assessment	
N20	Environmental management system accreditation for unconventional gas installation operators	MM	✓	✓	✓	✓		6,100	
N32	Competent Authorities have available sufficient inspection capacity and appropriately skilled inspectors	MM	✓	✓	✓	✓	✓	Qualitative Assessment	
29e	Site reinstatement plan	MH				✓		1,200	
30e	Muds restricted to approved list with known properties/safety data or, non-toxic drilling muds: *- approved list*	MH		✓				Qualitative Assessment	
30e	Muds restricted to approved list with known properties/safety data or, non-toxic drilling muds *- non toxic*	HH		✓				Qualitative Assessment	
v)	***Noise management and mitigation***								
51a	Maximum noise levels specified	MM			✓	✓		Qualitative Assessment	
51c	Noise screening installation: (i) screen drilling and fracturing rigs with noise barrier / enclosure; (ii) acoustic fencing around the site perimeter.	MM			✓	✓		40,400	
51d	Operational hours specified	MM			✓	✓		Qualitative Assessment	
51e	Vehicle routes specified	MM			✓	✓		Qualitative Assessment	
51f	Machinery orientation and selection to minimise noise	MM			✓	✓		Qualitative Assessment	
3a viii	Site baseline Undertake noise study	MM	✓					600	
3b viii	Monitoring Undertake monitoring of noise	MM		✓	✓	✓		11,000	
vi)	***Environmental Permitting and Assessment***								
N34	Public authorities produce an underground regional impact assessment to optimise resource allocation between unconventional gas and other underground resources (e.g. geothermal energy)	LL	✓					30	
N35	Member States implement integrated permitting for unconventional gas	LL	✓	✓	✓			Qualitative Assessment	
N15	Mandatory EIA for all projects expected to involve hydraulic fracturing, before exploration starts[4]	ML	✓					7,800	
N16 i	Mandatory EIA: (i) after initial phase of well exploration and before first test fracturing[4]	ML	✓	✓				7,800	
N16 ii	Mandatory EIA (ii) before production commences[4]	ML	✓	✓				7,800	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
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/prospecting and taking account of the entire project).	ML	✓					3,100	
N13	Member States carry out SEA of plans/programmes 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, land take, 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.	MM	✓	✓	✓	✓	✓	9,500	
N02	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	MM	✓	✓	✓	✓	✓	Qualitative Assessment	
N06	Operations to be subject to a 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	MM		✓	✓	✓	✓	4,600	
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	MM	✓					Qualitative Assessment	
vii)	***Transportation (including temporary surface pipes)***								
59a	Traffic impact assessment including consideration of noise, emissions and other relevant impacts	LM		✓				1,800	
59b	Transport management plan (including consideration of available road, rail, waterway infrastructure)	MM		✓	✓			600	
60c	Site selection close to water sources to minimise haulage requirements	MM	✓					Qualitative Assessment	
61b i	Minimise resources demands and hence traffic movements through (i) water management plans	MM		✓	✓			Qualitative Assessment	
61b ii	Minimise resources demands and hence traffic movements through (ii) wastewater management plans	MM	✓					Qualitative Assessment	
61c	Site selection close to wastewater treatment / disposal facilities to minimise haulage requirements	MM	✓					Qualitative Assessment	
3a vii	Site baseline Undertake transport and traffic study. Low ambition	MM	✓					600	
3a vii	Site baseline Undertake transport and traffic study. High ambition	MM		✓	✓			4,600	
3b vii	Monitoring Undertake monitoring of traffic numbers and patterns	MM		✓	✓	✓		3,100	

Measures		Level of Ambition [1]	Stage [2]					Impact Assessment [3]	Notes
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total annualised compliance cost (€ per pad)	Unless noted, all measures are complementary with each other.
60a	Use of temporary surface pipes for distribution of water supply	HH		✓	✓			Qualitative Assessment	
60b	Use of temporary surface pipes for collection of flowback	HH		✓	✓			Qualitative Assessment	
61a	Use of temporary surface pipes for collection of produced water	HH		✓	✓			Qualitative Assessment	

Notes
1. For key to level of ambition, refer to section 3.1.2.
2. Stage 1: Site identification and preparation. Stage 2: Well design & construction, hydraulic fracturing & well completion. Stage 3: Production (gas extraction and repeat fracturing). Stage 4: Project cessation and well closure. Stage 5: Project post closure and abandonment. For full descriptions refer to section 3.1.2.
3. Costs are in 2012 prices, annualised over 10 years with a discount rate of 4%. For definition of Low and High ambition, refer to Appendix D.
4. The point at which EIA is required is different for these measure options. Estimated EIA cost remains the same for each option.

Economic Impacts

The remainder of the section summarises the costs associated with the measures, using the same subdivision of measures as above. For full details of each measure, including costs, information sources and assumptions, the reader is referred to Appendix D.

Site Surface Conditions and Construction

Compliance Costs

This section focuses on ongoing monitoring/technical surveys associated with underground conditions which are classified as administrative costs. Compliance costs are nil or negligible.

Administrative Costs

Costs are considered qualitatively and quantitatively as follows:

- **Operators:** various baseline assessments relating to underground conditions, including:
  - **Baseline - drinking water abstraction points (3a iv).** Annualised costs are estimated at €1,200. It includes: the cost of geologist labour to list water wells within area (from public data); list the names and depth of all potentially affected underground sources of drinking water; provision of geochemical information and maps/cross section on subsurface aquifers; and obtaining water quality data and water gas content from existing available data;
  - **Baseline assessment of land conditions (soil) (3a v)** is estimated at €1,700;
  - **Baseline assessment of land use, infrastructure and buildings (3a xii)** is estimated at between €200 for a desk study (low ambition) and €500 for a desk study and aerial survey (high ambition).
- **Authorities:** There would be some costs incurred with administration and regulation associated with these activities.

Incident Response

Compliance Costs

A series of compliance costs have been identified and considered qualitatively, the extent of costs would be affected by the scale of any incident. These are:

- **Require consideration of major hazards for all stages in the life cycle (9a).** This includes early design, through operations to post abandonment and the development of a health, safety and environment (HSE) case or similar demonstrating adequacy of the design, operations and HSE management (including emergency response) for major impacts. The measure requires the identification and evaluation of major hazards for the whole life of the development, including those that may be presented from other neighbouring operations. Throughout the life of the development, the assessment would need to be updated. Changes to design, operational process and emergency response may be required, which could incur substantial costs;

- **Require emergency response plan to be developed and implemented (9b).** The measure would need to cover: well leaks to groundwater or surface water; releases of flammable gases; fires and floods; leaks and spillage of chemicals, flowback or produced water releases during transportation. The assessment would be carried out per pad and identify and evaluate potential incidents that could result in an emergency, across the whole life of the development. Costs would include the development of emergency response plans to manage events. The assessment would need to be updated and processes may need to be amended;

- **In the case of an incident/accident significantly affecting the environment, require operator to inform competent authority immediately (N08a).** Costs would include the management and staff costs of recording and reporting incidents. **N08b**, requires the competent authority to provide details of the circumstances of the incident and effects on the environment to a designated body at EU level that would then make non-confidential information available to the public, where similar staff costs would be incurred; and

- **Measure N09 requires operator to develop and maintain a contingency plan to address foreseeable impacts of operating conditions on environmental risk management.** Costs are estimated at some €9,900. Costs would be associated with the assessment/evaluation of foreseeable risks; development and maintenance of a contingency plan responding to risks, alongside consultation and liaison with the relevant regulatory/government body.

Administrative Costs

Measure 3b xix relates to monitoring and reporting associated with spills volume, nature, location and clean-up. The associated administrative costs are estimated at €2,000 for labour time and would be incurred by operators.

Assurance and Delivery

Compliance Costs

A series of compliance costs have been identified, these are:

- **Ensure equipment is compatible with composition of fracturing chemicals (N18).** This requires staff time for consulting with equipment manufacturers, chemical suppliers/manufacturers on compatibility and the effects of use. Depending on the outcome of such consultation, the costs may include the use of additional chemical products, for example biocides and/or substitution of chemicals with alternatives, which may in turn have economic and technical implications. It is likely chemical and equipment manufacturers would undertake ongoing research and development and testing programmes as part of their normal operations, although the use of certain chemicals in unconventional gas extraction may still be relatively new and untested. Similarly **30e (Restrict (drilling) mud to approved list with known properties/safety data or non-toxic drilling mud)**, requires operators to identify proposed drilling mud chemical additives. Competent Authorities would approve chemicals for use. Costs would be incurred in the assessment of proposed chemical additives (by Member States). Additional costs would be incurred for the identification and use of non-toxic/approved chemical additives (by operators);

- **Carry out thorough planning and testing of equipment prior to hydraulic fracturing operations (N19).** Costs would be incurred for equipment testing after installation but prior to start of operations, alongside consultation with equipment/substance providers. The measure may also require the physical presence of a number of technical specialists from some of the companies concerned, or an overall project manager coordinating contact with several suppliers. Additional costs would be incurred resulting from problems/equipment failures alongside cost associated with monitoring of equipment performance;

- **Environmental management system accreditation for unconventional gas installation operators (N20).** The measure examines costs associated with preparation and maintenance of EMS accreditation. Costs are estimated at some €6,100. It requires an initial audit, post audit design and support, health checking, staff training, internal audits and compliance checks. Allowance has been made for certification cost, which includes an application fee alongside operational costs associated with retaining the accreditation;

- **N36 requires operators to work together to ensure efficient provision of gas collection and wastewater treatment infrastructure,** requiring some limited co-ordination, with negligible costs;

- **N37 requires pad construction activities to be staged to reduce soil erosion and to coincide with low rainfall periods and N21 requires operators to clean vehicles.** N37 may restrict possible construction start/end dates and potentially contribute to shortages of skilled labour;

- **Site reinstatement plan (29e)** after well closure and abandonment to reinstate the site to its original condition. A cost of some €1,200 is estimated for preparation of the plan (remediation costs themselves are not considered); and

- **A baseline survey of site ecology and biodiversity (3a ix)** is estimated to cost some €6,500. The scope (and hence cost) will vary depending on presence of protected species and notable habitats and whether the sites is a designated site.

Administrative Costs

- **N28 (Competent Authority to explore technical and financial capacity/capability of operator and their contractors)**; and **N29 (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)) are likely to incur administrative costs in the preparation of evidence and insurance and legal costs in the preparation of financial guarantees;

- **The European Commission to develop further criteria/guidance for the assessment of environmental impacts from unconventional gas (N30).** This would require updates to EIA Guidance documents to cover Scoping; Screening and EIA. Fees for private consultants to prepare guidance related impacts of EC regulation could exceed €150,000. It is likely that given the requirements, that between 60 and 100 days of EC officer time would be required. Despite this, per pad, costs are likely to be negligible, and equates to some €20;

- Three measures relate to inspections. **N31 requires inspections by Competent Authorities during all stages of development** (e.g. of well completion reports and environmental risk management and controls) estimated at some €10. The estimate is based on annual time estimate for completion of EMS certification audit by external auditor. **N32 requires Competent Authorities to retain sufficient inspection capacity** to avoid bottlenecks in permitting/ delays in production, whilst **N33 requires further independent inspections**; and

- **Periodic monitoring surveys of biodiversity/ecology/invasive species (3b xvi)** estimated at some €900.

Monitoring (not elsewhere classified)

Compliance Costs

This section focuses on ongoing monitoring/technical surveys which are classified as administrative costs. Compliance costs are nil or negligible.

Administrative Costs

- **Operators:** a series of monitoring and reporting (M&R) measures are set out. M&R **- drinking water abstraction points (3b iv)** estimated at €2,400; M&R **- land conditions (soil) (3b v**) at €400; M&R **- energy source and use (3b xi)** at €2,000; M&R **- greenhouse gas emissions (3 b xii)** €2,000; and

- **Authorities: Member States to carry out strategic monitoring of unconventional gas activities at the level of the gas play to assess overall impacts and reaction as necessary (N27).** Costs are estimated at some €60. The costs include data collection/collation and publication of annual reports. Information to be collated to include exploration and production wells (drilled, active, and abandoned); volume of gas extraction; ground/surface water use; any environmental incidents, spillages, blow outs etc, environmental effects and remedial action; traffic movements and public complaints.

Noise Management and Mitigation

Compliance Costs

The installation of a noise barrier/enclosure on one drilling/fracturing rig is considered in 51c. **Acoustic fencing** around the site perimeter is also considered as part of the measure. Additional costs would be incurred on undulating ground or where sound attenuation mounds would need to be landscaped. Costs for this measure are estimated at some €40,400.

Administrative Costs

- **Operators: baseline – noise assessment (3a viii)** estimated to cost some €600 and **ongoing noise monitoring (3b viii)** estimated at €11,000; and

- **Operators and authorities: specify maximum noise levels (51a).** To comply, operators may need to provide noise mitigation on plant. Competent Authorities would need to assess the required maximum noise levels taking account receptors and impacts. Operator costs would include installation of equipment. Competent authorities would need to assess site specific maximum noise levels required and approve mitigation measures. Similar measures include **specifying operational hours (51d); specifying vehicle routes (51 e); and machinery selection and orientation on site to minimise noise (51f)** all of which are expected to incur similar costs. These are site specific and are not quantified.

Environmental Permitting and Assessment

Compliance Costs

This section focuses on permitting requirements, compliance costs are nil or negligible.

Administrative Costs

- **Operators: Member States to carry out Strategic Environmental Assessment (SEA) of plans/programmes before granting concessions for unconventional gas exploration and production and assess environmental effects of such plans (N13).** This assessment to address surface aspects such as water abstraction, waste treatment and disposal, transport, air quality, land take, species diversity as well as known underground risks. Costs for the preparation of these studies are estimated to be some €9,500 and allow for the assessment of Member State/concession level systemic effects. In addition, Environmental Impact Assessments (EIA) focus on effects related to individual projects. **N17 (EIA scoping) requires an assessment of whether a full project is likely to have significant effects on the environment during the early 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). Such EIA 'scoping and screening' are estimated to cost some €3,100 and will take place before a 'full' EIA and aim to focus those assessments on the most significant effects. **N15 would require a mandatory EIA for all projects involving hydraulic fracturing, in advance of any exploration activity. N16 i would require a mandatory EIA after the initial phase of exploration, before first test fracturing;** whilst **N16 ii would require a further EIA before production commences**. In each case EIAs costs will depend on the issues that would need to be considered and the degree to which work would or would not need to be repeated/updated but are assumed to be some €7,800. **7 also requires cumulative effects to be considered**, taking into account other (non unconventional gas) developments. Costs would be incurred on the assessment itself, alongside the costs of any mitigation, which are potentially significant;

- **N02 requires the operator to obtain an independent evaluation of risk management measures, before fracturing and at regular intervals thereafter**. In practice the requirements are likely to be similar to Quality Management System (QMS) accreditation and auditing requirements and/or the 'environmental statement' considering risks and their mitigation that is required as part of submission for EMS accreditation. **N06 is operators to be subject to a permit, which specify measures to manage environmental impacts**. This is expected to cost some €4,600. These costs include application preparation and for the application fee, along with ongoing evaluation/maintenance and application fees. The permits would need to be reconsidered every ten years, also incurring a (lower) fee; and

- **Authorities:** two measures focus on requirements for public authorities. **N34, mandates the production of an underground regional impact assessment**, to optimise resource allocation between unconventional gas and other underground resources (e.g. geothermal energy). Costs are expected to equate to some €30. **N35, Member States to implement integrated permitting for unconventional gas,** would enable operators to make a single or cumulative permit application for all of the required permits. Competent Authorities would need to develop and administer such a system.

Transportation (including temporary surface pipes)

Compliance costs

Compliance costs have been identified and considered qualitatively.

- Three measures relate to the use of temporary surface pipes, **60a for distribution of water supply; 60b for collection of flowback water and 61a for the collection of produced water**. Costs would comprise: installation of piping; pumping infrastructure and maintenance; obtaining of access rights to lay pipes; and removal of pipes after use. These costs would be offset by savings from reductions in water and wastewater haulage; and

- Similarly **60c is site selection close to water sources to minimise haulage requirements**. **61b requires water and waste management plans.** Whilst these may reduce cost as well as limit visual/noise impacts, some additional site selection/appraisal costs may be incurred. **Measure 61c is site selection close to wastewater treatment facilities**. This would require the identification of wastewater treatment plants and influence pad location options.

Administrative Costs

- **Operators: baseline traffic surveys** have been considered under low and high ambitions **(3avii)**. They require liaison with regulatory authority, identification of relevant routes to/from well pad area; and analysis of highway conditions. If bespoke traffic surveys are required, with traffic counts in a number of locations, (typically traffic counts are undertaken over one week period at c.4 locations) costs would increase. More complex traffic modelling based on the survey data may be necessary depending on the location. Low end estimate are some €600; a high end estimate could be up to €4,600 where these are in close proximity to built up areas or involve complex transport movements. Subsequent **traffic monitoring (3b vii)** is expected to cost around €3,100; and

- **Transport management plans (59b) and traffic impact assessments (59a).** For the former costs expected to be some €600 and for the latter costs are some €1,800.

Environmental Benefits

A number of measure combinations directly limit the magnitude of environmental effects (a number of the baseline and monitoring measures contribute to this alongside those related to incident response), whilst others seek to remove those risks (for example a number of measures associated with assurance and delivery). As such the measures covered here are likely to contribute to a range of environmental areas, such as biodiversity, soil and water quality and resources, waste production /recycling and to reduce the environmental effects of firms. Rapid and effective incident response is also likely to mitigate the impacts of major environmental incident, potentially including international impacts. The transport measures are likely to reduce transport movements, emissions and fuel needs although requirements for well pads in close proximity to wastewater infrastructure for example could lead to greater spatial concentrations of well pads, where appropriate infrastructure is accessible.

Social Impacts

The measures are likely to generate additional employment or sustain/safeguard existing employment in construction, transportation, in environmental consultancy and engineering, alongside additional needs for officer capacity within Competent Authorities to consider these assessments and provide wider regulatory capacity, including technical guidance.

Certain measures, for example integrated permitting, would result in some short-term administrative complexity as the associated systems are established, but the longer-term savings to both operators and Competent Authorities of a simplified system should offset this.

Further jobs are likely to be created directly, through installation and maintenance of these systems and their subsequent monitoring, and indirectly support/sustain employment along relevant supply chains, (in the provision of piping for example). The measures do not directly enhance job quality, but enhance public health and safety both directly and indirectly.

4. Policy Options to Deliver the Measures

4.1 Introduction

The impacts of measures to improve and/or assure the environmental performance of unconventional gas facilities depend, of course, on the degree to which they are applied. With regard to individual technical and other measures addressing themes such as underground risks, zoning, etc., these are set out in the previous section. The degree of application, however, depends upon the type of policy or instrument that might be used to take forward these technical measures.

This section, therefore, describes possible policy options which could be used to address these gaps in the control of unconventional gas facilities. It is structured around the following options:

- Do nothing (i.e. the baseline);
- Best practices and voluntary approaches by the industry;
- A recommendation and guidance to clarify the interpretation of certain pieces of EU legislation;
- Amendments of individual pieces of EU legislation;
- Dedicated instrument in the form of a directive to manage identified risks;
- Dedicated instrument in the form of a regulation to manage identified risks[33]; and
- A combination of various options.

This section examines the nature of each of these options and discusses the benefits and disbenefits in being able to address the risks from unconventional gas extraction allowing for the comparison of policy options as set out in the Impact Assessment guidelines.

4.2 Do-Nothing (Baseline)

One option is for no additional action to be taken of any kind. This is the baseline option. There are significant disadvantages to this option:

[33] In this analysis, both a directive and a regulation are referred to as options for delivery of a risk management framework. Within this report, a dedicated ‘directive’ should be read as being an instrument setting general principles (or ‘goal-setting’ legislation). A ‘regulation’ in the context of the current report would include specific detailed obligations. In practice, such specific detailed obligations could also be included in a (more prescriptive) directive, rather than a regulation.

- The option leaves the risk of negative impacts on the environment due to possible problems in the scope of the current regulatory framework as set out previously, a number of gaps have been identified;
- It does not address concerns raised by stakeholders on the operation of the industry sector and risks to health/environment;
- The option does not address the regulatory uncertainty that exists within the application of the existing *acquis*, which presents a business risk to the sector;
- It does not address the issue of regulatory fragmentation and/or duplication within the EU as Member States interpret existing EU legislation in different ways to address unconventional gas extraction or develop their own rules as may result from the reviews currently in place in a number of Member States; and
- While the option does not impose any new costs, it also does not reduce costs from regulatory uncertainty, etc.

The baseline option is not, therefore, a practicable option.

4.3 Best Practices and Voluntary Approaches by the Industry

Best Practices

This option assumes that the sharing of best practices by the industry sector would enhance the environmental performance of individual companies and facilities. Sharing of best practice by industry has the following advantages:

- The exchange is between technical managers which are fully familiar with the operation of such facilities and so could react quickly with new information received; and
- Such exchange could occur rapidly as new techniques are developed, new risks are perceived or understood, etc; and
- Such exchange could be facilitated in different ways, including by industry associations, the Commission, etc.

There are, however, limits on the ability of companies to share best practice. This is particularly the case where there is commercial confidentiality of aspects of the operation, as could be the case with the composition of the fracturing fluids.

The assumption underlying this option is that the environmental risks or impacts of a facility would be mitigated by the provision of new knowledge, i.e. that this is the principal barrier to improved performance. This, however, may be over optimistic. It would certainly not, on its own, allay the concerns of some stakeholders who may be sceptical of the motives of the sector. Having said this, the above advantages would suggest that some sharing of best practice (where this is possible) could enable a more rapid response to some environmental risks than other options and, therefore, the option could be effective as a support option alongside other possible options.

Voluntary Approaches

Voluntary approaches by industry are a specific sub-set of possible approaches within this option. Voluntary action could take various forms, from commitments on a particular issue by an installation, more detailed commitments by a company (which may be EU-wide) or the sector (e.g. within a Member State, but including several companies) to formal voluntary agreements agreed either at Member State or EU level.

The scope of a voluntary agreement could include any or all aspects of the operation of an unconventional gas facility (including exploration). Experience with formal agreements varies in the EU at Member State level. The Netherlands, for example, has a strong track record of their use (although it does not term them 'voluntary') and there is some positive experience in the UK. However, authorities in some other Member States have strong reservations about the approach.

At EU level there has been limited experience of the use of voluntary agreements. Examples include vehicle manufacturers and detergent manufacturers. In both cases the necessary precondition for an agreement has been a coherent and relatively comprehensive industry representative organisation at EU level with which the Commission could negotiate an agreement. With unconventional gas it is not clear if this condition is in place (or would remain in place with significant expansion of the sector). However, it might not be an insuperable problem. Having said this, experience with implementation of voluntary agreements across the EU has been variable (e.g. for detergents it has since been replaced by a regulatory approach).

As a policy approach, choosing a voluntary agreement route would not guarantee any outcomes at the outset. Therefore, stakeholders would not know (and therefore be confident) whether concerns would be addressed. However, if this option were to be preferred, the Commission could state explicitly at the outset both the range of issues that it would expect to be included in an agreement and the timetable for the negotiation. This might allay concerns and failure to complete the negotiation could be backed-up by the 'threat' of a regulatory approach as an alternative.

In conclusion, the potential benefit of a voluntary agreement cannot be known, but would be problematic if the whole sector has not signed up. Sharing best practice, etc., would only be effective if the information shared presented an obvious benefit to the operator. Further voluntary agreements could be time consuming to develop and there could be fragmentation within the industry sector. However, sharing best practice would be easier to establish, but issues of commercial confidentiality, etc. might limit the scope of such sharing.

4.4 A Recommendation and EU Guidance to Clarify Interpretation of EU Legislation

The review of current EU legislation has noted that some items of legislation are adequately formulated to address unconventional gas extraction. Examples include the SEA Directive which (if applicable, i.e. if there is a plan or programme setting the framework for unconventional gas projects and if it is applied correctly) should consider the cumulative impacts of extraction from several sites, etc., and the Habitats Directive and its requirements for appropriate assessment. However, in such cases Member States (and particularly local regulatory or planning authorities) may struggle to understand the implications of unconventional gas extraction for the requirements of these Directives. Thus while legal amendment is not needed, the development of guidance tools at EU level, taking into account good practices in Member States and elsewhere, could be beneficial in ensuring proper implementation. Examples of potential guidance that could be developed to support the interpretation of existing legislation with regard to unconventional gas are set out in the table below.

Table 4.1 Potential Guidance to Support the Interpretation of Existing Legislation

Legislation	Scope of potential Guidance
SEA Directive	How to address cumulative impacts of several facilities within energy plans, etc., in particular for less familiar risks, such as underground risks
Industrial Emissions Directive	Guidance on how far unconventional gas facilities are included within the scope of IED
Mining Waste Directive	The storage and treatment of waste and requirements of the MWD
Water Framework Directive (and daughter Groundwater Directive)	The risks posed by unconventional gas facilities to ground and surface waters and, in particular the specific objectives of the Directives (Good Status and individual EQS). Guidance could also address specific issues of surveillance and investigative monitoring and use of supplementary measures within Programmes of Measures

Guidance produced under these Directives is familiar to Member States and, therefore, its introduction would be through existing processes. The use of guidance can explore appropriate techniques for different situations, address evolving developments and build on good practices.

When considering this option, it needs to be noted that the scope of interpretative guidance is limited to existing EU legislation. Not all of the risks of unconventional gas extraction are adequately addressed by current legislation, e.g. geological and hydrogeological aspects and induced seismicity. Aspects going beyond the existing *acquis* may be addressed by a recommendation to Member States (non-binding), inviting them to follow certain measures or principles. A recommendation could propose that aspects such as those presented in Table 4.2 are addressed by Member States where high volume hydraulic fracturing for hydrocarbons is intended to be used.

Table 4.2 Potential Aspects of a Recommendation

Aspect	Description
Strategic environmental assessment	An SEA is carried out prior to granting licences.
Environmental impact assessment	An EIA is carried out prior to hydrocarbons activities using high-volume hydraulic fracturing.
Baseline and operational monitoring	Baseline groundwater, surface water, air quality and background seismicity, to provide a reference point for subsequent monitoring and in the event of an accident. Monitoring of fracturing fluid composition, water use, flowback volume and emissions to air.
Site specific risk characterisation and assessment	Related to underground and surface environments, to determine whether an area is suitable for exploration or production. The assessment would *inter alia* identify risks of exposure pathways (e.g. induced fractures, existing faults or abandoned wells).
Well design and integrity testing	To ensure the well is properly constructed and is isolated from the surrounding geological formations and integrity is maintained throughout the well lifetime.

Aspect	Description
Operational requirements	For example regarding water management, transport management and risk management plans and incident reporting requirements.
Public disclosure of information	Of baseline data, monitoring data and the composition of fracturing fluid and wastewaters
Control of releases to air	Venting of gas into the atmosphere is limited to exceptional operational circumstances (e.g. safety), controlled gas flaring is minimised, and gas is captured for use.
Application of best available techniques	BAT would need to be defined in a BAT reference document that may draw on experience from Member States, industry and other organisations with an interest in environmental protection.
Enhance knowledge on technologies and practices	Through the establishment of an information exchange network involving industry, environment organisations, academia and civil society
Resources and knowledge of the process	Permitting authorities have sufficient resources and knowledge to ensure adequate risk management and to avoid administrative burden for operators
Pre-operations consultation	Consultation of stakeholders before operations commence

A recommendation and guidance are able to be adopted relatively quickly (compared to legislation). Furthermore, given the evolving nature of the sector, such approaches could be readily amended to take account of new developments.

However, a recommendation and guidance are not binding. Where they provide advice about good practice, there is no obligation to follow it. It is not known how receptive Member States would be to different types of guidance or a recommendation, nor how willing the industry sector would be in supporting their use. Ensuring consultation of Member States, the sector and other stakeholders in the preparation of guidance or a recommendation may increase subsequent buy-in.

The costs of this option are simply those of developing a recommendation and guidance themselves. This would vary depending on the complexity of the issue being addressed and on the ability to use existing fora to develop guidance.

4.5 Amendments of Individual Pieces of EU Legislation

The regulatory gaps in the existing *acquis* could be partially filled by amending the existing *acquis*. The nature of the potential amendments varies significantly. In some cases the amendment would be relatively minor ensuring that an aspect of the operation of an unconventional gas facility is included in the scope of a Directive. In other cases the amendment could be significant aiming to encompass much of the operation of such a facility.

The table below provides examples of amendments to the existing *acquis* which could be used to address the gaps in the regulation of unconventional gas extraction facilities.

Table 4.3 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.

Amendment to IED has a number of attractions. Extraction and exploration for unconventional gas could be explicitly included within Annex I. Doing this would ensure the full provisions of IED are applied. The changing nature of techniques would be picked up under a changing understanding of BAT and provisions relating to other areas of environmental protection (e.g. water) would be captured. However, it is arguable that IED cannot address all of the risks associated with unconventional gas extraction. In particular, some underground risks are not associated with pollution as defined by IED. This suggests that while full inclusion within IED would have significant benefits, it is not a solution to all of the identified risks (noting that these include some of most public concern).

A major disadvantage to this option is that it would probably need to be taken forward as opportunities arise to amend the respective Directives. For some (e.g. EIA) there may be an early opportunity, but for others this would be several years away (e.g. review of the Water Framework Directive is not until 2018 and adoption of any amendment after this). This means that using this option would only deliver partial results in the short-term and would result in a piecemeal approach for several years. Given the concern over regulation of the sector now, such a delay is probably unacceptable.

In theory another approach to introducing the necessary amendments would be to propose an amending Directive which includes, in one go, a suit of amendments to other legislation. However, if this route were chosen it would have little practical benefit over a dedicated instrument (see below) and be potentially less coherent in its outcome.

In conclusion, not all risks associated with unconventional gas could be addressed through amendments of existing law unless the fundamental scope of that legislation is changed. Relying on the review periods of existing legislation to introduce such amendments would take several years and result in a potential patchy progressive adoption of changes with problems of coherence in the *acquis*.

4.6 Dedicated Instrument to Manage Identified Risks (Directive or Regulation)

A new dedicated instrument on unconventional gas extraction (covering exploration and production) is the final main option. Such an approach has a major advantage over the amendment of existing legislation in that it could address all of the issues concerned with unconventional gas extraction, as it is not limited by the scope of pre-existing legislation.

It is important to note that the evolving nature of unconventional gas extraction, with new techniques, new understanding of risks, etc., is not an impediment to developing an instrument. This would only be the case if the instrument prescribed in detail the types of techniques or approaches to be used in the process. However, if the instrument sets out obligations in a similar way to the IED, it could require the application of BAT to unconventional gas extraction, supported by a dedicated BREF and potentially more binding BAT-conclusions. BAT is a moving concept and, therefore, the expectations for the performance of an installation could change as techniques, etc., evolve.

The scope of a potential new instrument need not be set out in detail here, but it would be expected to address the main risks identified in this study for unconventional gas extraction. This would require the scope to be wider than that of IED (see above), but the regulatory approach could be similar. It would be appropriate for an instrument to set overarching goals and objectives for operators, including on understanding the potential hazards of extraction, assessing environmental risks, minimising potentially harmful activities (e.g. types of chemicals used), reducing emissions to air and water, minimising and managing waste, etc. A legal instrument could set more detailed requirements with regard to assessment, monitoring, site closure, etc.

The development of a dedicated instrument has the strong advantage that it could deliver full coherence for the regulation of the sector which is not guaranteed by amending the suit of existing legislation to fulfil the same general purpose (previous option). The CCS Directive is an example of such a dedicated instrument aimed at managing risks, some of which (particularly those regarding underground) are similar to those presented by unconventional gas.

A dedicated legal instrument could be either in the form of a directive or a regulation. A directive requires transposition into Member State law, while a regulation is directly applicable. The comparison between these two types of instrument is considered further below.

4.7 A Combination of Various Options

The options set out above are not mutually exclusive and, indeed, it may be useful to consider taking forward action under more than one option. There are two types of mutually supportive interventions:

- Where action would be required under more than one option for coherent action to take place;
- Where action under more than one option would benefit the coherence or effectiveness of the preferred approach.

The situation where action would be required under more than one option is most evident where the preferred type of intervention is for a dedicated legal instrument in the form of a directive or regulation. While such an instrument could set out all of the necessary obligations regarding unconventional gas extraction covering all of the themes described in Section 3, it would also be necessary to amend some items of pre-existing legislation to ensure that there is coherence between a new instrument and these instruments. Examples are set out in the table below.

Table 4.4 Examples of Possible Amendments to Existing Legislation that could be Appropriate alongside Adoption of a New Dedicated Instrument

Existing EU Instrument	Example Amendments if a New Dedicated Instrument is Preferred
EIA Directive	Clarity on the scope of application of EIA particularly for exploration stage is needed.
Mining Waste Directive	Amendment needed to clarify coherence with a new instrument, whether some aspects are still addressed by the MWD or its provisions do not apply as all is addressed in a stand-alone instrument.
Water Framework Directive (and daughter Groundwater Directive)	Amendment ensuring that controls on injection of wastewaters (flowback and produced water) for disposal are considered compliant if they meet the requirements of a new instrument.
Environmental Liability Directive	Amendment needed to include activities permitted under a new instrument as with others are included within Annex III of ELD.
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 (as with IED).
IED	If the new instrument addresses all that would otherwise be included within IED, IED would need to be amended to clarify exclusion of this type of installation.

A major difference with dedicated amendments to pre-existing legislation is that the amendments in the table above could be taken forward outside of the normal review cycles of the respective Directives. As with the CCS Directive, such amendments could be included within the text of the new instrument itself and, therefore, all necessary legislative changes delivering the necessary legal and practical coherence could be delivered at the same time.

The second area of interaction between options is where action under more than one option would benefit the coherence or effectiveness of the preferred approach. This concerns the interaction between non-legislative approaches and legislative approaches and could apply equally with adoption of a new dedicated instrument or amendment of pre-existing legislation.

The application of the details of a new instrument, or amended existing instruments, would require interpretation and support. Therefore, the development of guidance or tools at EU level drawing on sharing of best practice in the Member States (and elsewhere) would be beneficial in ensuring proper implementation of these new rules. It is suggested in the discussion of the options for a new instrument or amendment to IED and/or MWD that a dedicated

BREF could be developed. This would, therefore, provide much guidance at least at a technique level. However, it would also be beneficial to provide guidance on aspects of prior assessment of an exploratory or operational facility, such as on assessing potential seismic risks, zoning and the interaction with EIA, risks of transfer of pollutants in aquifers, etc. Generic guidance for regulators, etc. might also be appropriate.

4.8 Selected Policy Options

4.8.1 Introduction

This section presents a description and comparison of four selected policy options based on the initial analysis set out above. 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.[34]

This section, therefore, will begin with a brief description of each of the policy options. It will then compare these options in terms of the measures addressed by those options and their potential effectiveness and efficiency, concluding with the pros and cons of each option. Comparative analysis in relation to the costs of the options is subsequently presented.

4.8.2 Policy Option A: Recommendation plus Guidance

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 address legal gaps. Such a recommendation provides non-binding actions with no obligatory power that may provide preparation for legislation (if deemed necessary) in Member States. With regard to unconventional gas, this study has identified a wide range of issues arising in the interpretation and application of individual Directives together with gaps in the legislation that could be elaborated through guidance and a recommendation. Such material would reduce

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

uncertainty by operators and provide assistance to regulators who may be uncertain whether they are correctly implementing EU law in this evolving area.

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 were explored above.

4.8.3 Policy Option B: Amendment to the Acquis plus Guidance

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

Section 4.5 described the basis for addressing the regulatory gaps in the existing *acquis* by amending the existing legislation. As was noted, the nature of the potential amendments would vary significantly. In some cases the amendment would be relatively minor ensuring that an aspect of the operation of an unconventional gas facility is included in the scope of a Directive. In other cases the amendment could be significant aiming to encompass much of the operation of such a facility. Option B would further support the implementation of the existing legislation through the adoption of guidance, voluntary agreements and sharing of best practice. Examples of possible amendments were set out in Table 4.3.

The development of guidance therefore, would be on the same basis as Option A, except that the amendment of existing legislation would require additional guidance to be developed and best practice to be shared on additional elements adopted in the amended legislation. Furthermore, amendment of the IED and 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.

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.

The extent of the specific measures that can be included in this option and the comparative effectiveness and efficiency of this option is explored in Section 4.8.6.

4.8.4 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.

Section 4.6 described the basis and potential scope of a new dedicated instrument, so this will not be repeated here. The scope of such an instrument would be able to be wider than that of amending the existing *acquis* as would be undertaken in Option B. All issues associated with the exploration and production of unconventional gas could be included.

Furthermore, such an instrument can be supported with the adoption of guidance, voluntary agreements and sharing of best practice. 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.

4.8.5 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. This would include the elements described in Section 4.6. A regulation would readily include prescriptive elements of an instrument. 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.

4.8.6 Comparison of the Options

In this section the principal points of comparison of the options are the range of measures that could be addressed by each option as well as the efficiency and effectiveness of those options (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[35] are presented in Appendix F. For each of the four options, the table highlights those measures that would be potentially addressed by that option. Note that this is a broad assessment assuming, for example, wide co-operation with stakeholders in the development of guidance to enable many issues to be addressed or that a dedicated instrument was designed to be wide enough in scope to address a wide range of concerns.

[35] Based on measures identified through the present study, the Commission selected those that would apply under each policy option.

It can be seen that all four options can take forward many measures. Option A would address 160 measures, Option B, 172 measures and Options C and D, 196 measures. Options B, C and D include all measures that can be addressed by Option A.

Key measures that Option B could address that are not taken forward by Option A are:

- EIA for projects expected to involve hydraulic fracturing before exploration commences;
- Legal clarification of provisions on waste management, water and air protection;
- The adopting of a series of measures to maintain well safety;
- Microseismicity monitoring and management requirements during operations; and
- Good practice on deconstruction for site closure.

Key measures that Options C and D could address that are not taken forward by Option B are:

- Member States to carry out strategic environmental assessment (SEA);
- Mandatory EIA including public participation;
- Baseline reporting and monitoring requirements;
- A prevention and contingency plan for underground risks;
- Disclosure of chemicals used on a well by well basis;
- Capture of gases from the well;
- Provision of financial guarantees and financial contribution by the operator covering the entire lifecycle of the project;
- Post closure inspection, monitoring and maintenance programme[36]; and
- Competent Authorities to have sufficient inspection capacity.

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 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 always be more effective than non-binding instruments. However, this depends upon the reasons for the gaps in measures that the options aim to address.

[36] The Mining Waste Directive includes provisions on closure and post-closure of waste facilities. Measures included under the options (see section 3.9) would develop more specific provisions.

If a lack of implementation of measures is due to a lack of knowledge (including by regulators in smaller Member States with limited capacity), then the development of guidance and supporting tools at EU level could address this. In this case Option A would be efficient and effective. However, where there are concerns that measures adopted within Member States are creating differences across the EU and the 'level playing field' is being compromised, then non-legislative instruments are not likely to be effective at delivering the desired outcomes.

Furthermore, there are likely to be cases where environment and health may be put at risk from unconventional gas extraction even where potential mitigating measures are known. In these cases a non-binding approach will not address such concerns and would be ineffective at delivering the desired outcomes.

Finally, it is important to recognise that a critical aspect of Option A is that guidance aids in the interpretation of existing law and this includes guidance to ensure that law is correctly applied. Thus this Option aids the efficient application of current legislation.

Therefore, Option A is efficient in helping to ensure effective implementation of existing law and would be effective where knowledge limitations are the limiting factor in implementing measures. However, the Option is not efficient in addressing situations where environmental and health protection is not a political priority. Furthermore, it is not able to address in a significant way issues of coherence between existing legislation.

Options B, C and D are able to address these limitations of Option A by ensuring that the legislative and implementation gaps are filled by amended or new legislation which is binding in nature. Furthermore, where interpretive guidance or tools are deemed to be appropriate or effective (e.g. in exploring knowledge gaps or interpreting law), both Options include the development of guidance and sharing of best practice, so that these benefits are retained.

The principal differences between Option B and Options C and D are:

- The timing of the adoption of the Option;
- The scope of measures that can be addressed by the Option; and
- How far the Option delivers policy coherence.

Options C and D are both stand alone instruments and, therefore, can be taken forward as with any other new instrument. Based on previous analysis (including this study), the scope and detail of the instrument can be drafted and consulted upon, leading to the proposal being adopted through the normal legislative procedure. There is no reason for any delay in taking forward this option. Thus the development of the option is efficient.

In contrast Option B is based on amending existing law in a piecemeal approach, relying on review timetables in legislation. For example, the EIA directive is currently being debated, but the Water Framework Directive will not be reviewed until 2018 at the earliest. As a result where certain amendments are needed to take forward specific measures, some of these will be many years away from being introduced into law. This represents a major delay and is particularly inefficient. The problems this would generate include:

- A lack of certainty as to which measures would be finally agreed (there being no guarantee that all proposed amendments would be adopted);

- A piecemeal approach to introducing new measures leading to uncertainty for regulators and operators as the regulatory framework will be subject to repeated revisions;

- The extended timetable would present problems for regulators and operators of facilities that are coming on stream now and in the early to medium term as the agreed conditions could change due to legislative change with resulting costs; and

- The staggered approach would present significant policy coherence issues, even if the end result could deliver increased coherence.

The second issue is the range of measures Option B can address. As noted above there are certain measures that it would not include. These include contingency planning, financial guarantees, etc. In effect, the scope of Option B is limited to what existing legislation can be reasonably expected to encompass. There is, furthermore, a question of how far existing legislation can be reframed to address underground issues without changing the fundamental nature of that legislation. At this stage, it can be argued that a particular Directive could be amended to include such measures, but in practice it is far from certain that others would agree that such measures would be appropriate for each Directive. As a result, not only is Option B ineffective in taking forward all of the necessary measures, it is likely to be inefficient in delivering the measures that at this stage seem potentially possible under this Option. Options C and D, however, are not subject to these constraints and are therefore, more effective.

Finally, on the issue of policy coherence it is important to note that, while Option B could in theory deliver improved coherence, it is likely that amendments designed today to achieve this would not survive in that form as all of the amended Directives are adopted and changes would lead to reduced coherence. Options C and D would ensure internal coherence within the instrument and the measures it contains. Furthermore, where existing legislation must be amended, such amendments can be included within a new instrument (as was the case with the CCS Directive), thus delivering increased coherence.

In comparing Options C and D the primary point of comparison is the nature of the legal instrument. A major difference between a directive (Option C) and a regulation (Option D) is that the latter has direct effect and, therefore, its provisions should not need transposition. Thus the implementation delays that could occur due to transposition failures with Option C are avoided. Furthermore, variations in interpretation in national law through transposition are less likely. In the present report, it is also assumed that more specific and detailed provisions could be adopted under Option D than under Option C.

However, in practical terms, this benefit of Option D depends upon the precise nature of its provisions. Where the implementation of the provisions of an instrument require significant interpretation, it is difficult to set these out in a regulation. Indeed, they may not only require practical interpretation, but clarification in national law. For example, in considering IED, the general regulatory requirements need such interpretation as these contain flexibility to tailor regulatory action to different types of activity with different risks. In contrast, the emission limit values in the Annexes could in theory be set out in a regulation as these are precise (albeit not necessarily a guarantee of BAT).

Depending on the exact nature of the details of an instrument, issues of practical coherence with other EU environmental law could arise with Option D. Where directives such as EIA, IED, Water Framework, Waste Framework, etc., have been interpreted at Member State level (including the administrative provisions of those directives), a directly applicable regulation might raise unintended complications for integration of these provisions with the interpreted provisions of directives. This would not be the case with a directive (Option C).

If a new legal instrument on unconventional gas would need to contain some regulatory flexibility, then Option C would be an advantage over Option D. For example, the instrument might need to address all operational actions from initial exploration to site closure (and beyond) as well as the many varied types of facility in different circumstances and locations. If so, some flexibility might be required. Thus a directive (Option C) which is binding as to objectives and not means might be preferred. Furthermore, the techniques of unconventional gas extraction are still developing, so the degree of prescription which would be needed for a regulation would be inappropriate. As a result, it seems that even given the benefit of direct applicability, Option C is probably more appropriate than Option D.

4.8.7 Policy Option Costs

Cost of Measures under Each Policy Option

For some 230 non-BAU measures (including sub-measures) identified to address (partially or fully) specific environmental risks, costs and benefits were 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. The cost estimates were based on the key assumptions made in the illustrative concession (see Appendix B) and labour costs for operators, external technical experts and competent authorities[37]. All costs have been adjusted to 2012 Euro prices using historical exchange rates (annual average) and Eurostat annual average index of Harmonised Index of Consumer Prices (HICP).

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. In most cases, the capital cost was

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 theEU-27 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-27 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.

assumed to be amortised over 10 years (i.e. the assumed average lifetime of a well pad). For measures where different amortisation periods were applied, this was noted in the key assumptions. 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 Option A, the high end costs assume that the 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 a Low ambition measure was selected and a High option was available.

Table 4.5 presents the annualised compliance costs for different policy options, showing the split between 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 by the Commission 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.

Table 4.5 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**
Operators	*0 to 1,512,000*	*1,512,000*	*1,578,000*	*1,674,000*
Authorities	*0 to 2,000*	*2,000*	*12,000*	*12,000*

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.

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 3.1.2 some of the measures are likely to be normal practice by operators. For instance, measure 22a on *key elements to maintain well safety*[38] comprises many

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).’

elements that are normal industry practice design, 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 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 adopted 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, 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 were assumed for the measures that were considered to be *likely to be applied* (i.e. 90% uptake level) and 60% 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 4.6. 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.

Table 4.6 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

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 667,000	667,000	729,000	825,000
Operators	*0 to 666,000*	*666,000*	*718,000*	*814,000*
Authorities	*0 to 1,000*	*1,000*	*10,000*	*10,000*
Difference compared to pre-adjustment	*Up to 44%*	*44%*	*46%*	*49%*
Total annualised compliance costs , with adjustment for non-BAU measures *likely to be applied and possible to be applied* in practice	0 to 596,000	596,000	654,000	737,000
Operators	*0 to 595,000*	*595,000*	*643,000*	*727,000*
Authorities	*0 to 1,000*	*1,000*	*10,000*	*10,000*
Difference compared to pre-adjustment	*Up to 39%*	*39%*	*41%*	*44%*

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.

One of the most significant contributors to the annualised compliance costs for policy options is measure 22a on *key elements to maintain well safety*. To estimate the cost of this measure, a 10% cost increment to drilling and cementing service costs was assumed as suggested in the Golden Rules report by IEA (2012). Assuming a typical well cost to completion is $8 million in the US and the cost in Europe is 30% to 50% more expensive, this incremental cost is approximately €870,000 per well and €7 million per a well pad, which leads to an annualised compliance cost of around €860,000 per pad in 2012 prices. This measure, included in Options B, C and D, accounts for more than half the total annualised compliance costs of the policy options. Nevertheless, this measure is assumed to be likely applied in practice, and therefore only 10% of its annualised compliance cost (i.e. €86,000) has been taken into account when similar adjustments are made (as shown in Table 4.6). This measure is not included in Option A.

Another measure of note is 3a iii *Site baseline: undertake sampling of ground water (Very High Ambition: boreholes to sample deep groundwater and characterise hydrological series)*. The cost estimate assumes drilling four deep boreholes to sample groundwater at 400m depth, and the capital cost of drilling, installing permanent pumps to allow sampling, sampling and analysis[39] is estimated as approximately €1.2 million per pad, with an annualised compliance cost of around €150,000 per pad. Drilling boreholes is the largest cost component of this measure due to the high cost and technical nature of drilling and constructing such a deep sampling borehole. This measure accounts for some 10% of Options. If a less ambitious sub-option (3a iii *High Ambition: sampling of shallow groundwater during wet and dry periods)* were selected instead, the annualised compliance costs would be much lower at some €1,200 per pad, without the need to drill deep boreholes.[40]

Administrative Costs of Policy Options

Sections 3.2 to 3.11 of this report cover the compliance costs and administrative costs associated with the various measures to address environmental risks associated with unconventional gas extraction. However, it is important to recognise that there would also be costs to both operators and authorities associated with the policy option(s) used to implement the various measures. The following table provides a high-level overview of the types of costs to operators and authorities that would be likely to arise for each of the three policy options together with the baseline option.

39 Analysis for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, gas isotopic fingerprinting, radioactivity and heavy metals.

40 Note that 3a iii *Site baseline: undertake sampling of ground water (Very High Ambition: boreholes to sample deep groundwater and characterise hydrological series)* is not considered *likely to be applied* or *possible to be applied* under normal practice thus no reduction is applied to the cost when included in the total cost of policy options.

Table 4.7 High-level Overview of Types of Costs associated with Possible Policy Options

	Costs to Operators	Costs to Authorities
Do nothing (baseline)	No additional costs	No additional costs
Option A. EU Recommendation plus Guidance	Costs of interpretation of guidance and determining applicability to individual operations	Costs of time associated with interpretation of guidance for national situation to provide to operators (would not be needed in all cases)
Option B. Amendments of individual pieces of EU legislation together with guidance	Incremental costs of additional requirements under each existing Directive (e.g. additional permitting requirements under IED, MWD, Water Framework Directive) Operating costs for additional monitoring and reporting under the respective legislation Costs of interpretation of guidance and determining applicability to individual operations	Costs of developing and amending regulatory regimes for each piece of legislation and costs of regulatory effort in inspections, enforcement, etc. (potentially spread across several competent authorities or regulators) Costs of time associated with interpretation of guidance for national situation to provide to operators (would not be needed in all cases)
Option C. Dedicated instrument (directive setting overall goals) to manage identified risks together with guidance	Costs associated with e.g. a possible over-arching/integrated permitting regime for unconventional gas Operating costs for additional monitoring and reporting under the respective legislation Costs of interpretation of guidance and determining applicability to individual operations	Costs of developing a permitting regime in each Member State and costs of regulatory effort in inspections, enforcement, etc. Costs of time associated with interpretation of guidance for national situation to provide to operators (would not be needed in all cases)
Option D. Dedicated instrument (a regulation with detailed prescriptive requirements) to manage identified risks together with guidance	Costs associated with e.g. a possible over-arching/integrated permitting regime for unconventional gas Operating costs for additional monitoring and reporting under the respective legislation Costs of interpretation of guidance and determining applicability to individual operations	Costs of developing a permitting regime in each Member State and costs of regulatory effort in inspections, enforcement, etc. Costs of time associated with interpretation of guidance for national situation to provide to operators (would not be needed in all cases)

All four policy options include the development and use of guidance. The scope of the guidance would vary with each option (e.g. whether based on different aspects of EU policy for Option B or relating to a dedicated instrument in Options C and D). At this point, however, it is not possible to identify the exact extent (and therefore cost) of guidance under each option. Rather it is assumed that a similar level of costs would be associated with the development and use of guidance for all options. It could be argued that Option A, which is only based on the use of guidance and a recommendation, could involve development of more guidance than other options as no legislation would be developed. However, while this might be the case, without reference to binding law, the potential costs to national authorities and operators could be less as they would be under no obligation to follow this guidance and the recommendation.

The administrative costs of the legislative options concern the permitting of installations and the ongoing monitoring, reporting and inspection of those installations once they are operating. Examples of costs include:

- Costs to regulators of permitting:
  - Analysis of permit applications;
  - Public consultation;

- Interaction with operators; and
- Placing permits on registers.

- Costs to operators of permitting:
  - Determination of appropriate operating costs, e.g. compared to BAT (or similar);
  - Permit application development; and
  - Addressing issues arising from regulators and possible revision of the permit application.
- Ongoing costs to regulators:
  - Analysis of reported monitoring data; and
  - Inspection (preparation, undertaking inspection, reports, follow-up).
- Ongoing costs to operators:
  - Monitoring of operations, emissions, etc.;
  - Reporting of monitoring results to regulators;
  - Being available for inspection; and
  - Addressing issues arising from inspections.

To assess these administrative costs it is best to start with Option C – a dedicated directive with guidance.

Estimates of the costs of permitting of unconventional gas installations draw upon experience of the costs of other similar regimes. The most comparable regimes are those of carbon capture and storage (CCS) and Industrial Emissions, and it is assumed that the administrative costs would be of a similar order for unconventional gas exploration. The tables below show the one-off (initial) costs and repeated ongoing costs firstly to operators and then to administrative authorities based on the figures used in the Impact Assessment for the (then) proposed CCS Directive[41].

41 Commission Staff Working Document Accompanying Document To The Proposal For A Directive Of The European Parliament And Of The Council On The Geological Storage Of Carbon Dioxide, Impact Assessment, 23 January 2008. This in turn was based on the approach in the Impact Assessment for the Industrial Emissions Directive (revision of IPPC).

Table 4.8 Administrative Costs to Operators

Type of Obligation	Description of Action	Tariff (€ per hr)	Time (hr)	Price per Action
Application for exploration permit	Producing the required information	65	40	2,600
Application for operational permit	Producing the required information	65	308	20,020
Application to change, review of update an operational permit	Producing the required information	65	100	6,500
Ongoing collection of new monitoring data and submission of reports (ongoing cost)	Producing the required information	65	90	5,850
Compliance assurance (ongoing cost)	Working with regulators on inspection and compliance checking	65	4	260
Closure of the site	Revision and acceptance of closure plan	65	40	2,600

Table 4.9 Administrative Costs to Member State Administrations

Type of Obligation	Description of Action	Tariff (€ per hr)	Time (hr)	Price per Action
Application for exploration permit	Administrative efforts to assess permit application	65	24	1,560
Application for operational permit	Administrative efforts to assess permit application	65	145	9,425
Application to change, review of update an operational permit	Review of the updated permit application	65	40	2,600
Compliance assurance (ongoing cost)	Inspection and compliance checking of facilities	65	24	1,560
Reporting to Commission (ongoing cost)	Provision of data to EU level reporting	65	24	1,560

For a single pad, therefore, the total start-up administrative costs associated with administrative costs of a risk management framework for exploration and production would be 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 for each well pad. The tables provide costs for permit review (which may or may not be required) as well as site closure.

These figures are based on individual pads. An unconventional gas concession would have many pads (the illustrative concession used in this study assumes 250 pads per concession), but these would progressively be taken forward over many years so there would be many efficiencies in permit development drawing on data from earlier site applications and operation. It is, therefore, not possible to provide a reliable cumulative figure for administrative costs at EU level.

It is important to note, however, that these costs would not be net costs. A dedicated instrument (Options C or D) would replace elements of the following:

- The need for permitting of aspects of a facility under other parts of EU law (e.g. IED, MWD); and
- Any nationally developed permitting regimes.

Therefore, in some cases, the introduction of a new dedicated permitting regime could result in limited additional costs to both regulators and operators depending on the extent to which other regulatory regimes are in place.

Option B involves the amendment of individual items of legislation. These amendments would require a change in the required operating conditions of an installation and, therefore, a review of the permits. However, many unconventional gas facilities would not be operational and, therefore, would be subject to an initial permit application rather than a review.

The IED Impact Assessment concluded that for large installations a permit review would result in costs to regulators of €5,000 and to operators of €2,500. Therefore, such costs would be imposed on operators of existing facilities for each permitting regime for which they have a permit.

Assuming that the principal amendments would focus on the IED, EIAD, MWD and Water Framework Directive, a range of different permitting regime conditions would be affected. However, if the facility is a new one, it is not clear that an amended Directive would result in additional costs to either regulator or operator compared to the existing *acquis* (other than some possible monitoring requirements). For example, it is not evident that permitting costs would be different for a permit under an amended MWD than under the current Directive.

Having said this, the current regulatory landscape could require an operator to obtain several permits. Therefore, Option B would not address these administrative burdens as effectively.

4.9 Policy Option Affordability

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 of unconventional gas extraction facilities. As a simplified approach, 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.

Assuming an annual gas production rate of 6-19mcm over a 10 year well lifetime[42], gas production per pad, per year (assuming eight wells per pad) would be in the order of 45-148mcm. The current price of natural gas in

[42] European Commission data (personal communication based on JRC IET study) suggest 56-185mcm per well based on 30 year lifetime. However, a 10-year lifetime is assumed in the current analysis. Taking into account the significant drop-off in production rates 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 have been divided by 10 to give an estimated annual production value.

Europe is estimated[43] 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).

The table below compares the quantified costs under each of the policy options to the expected revenues, using the midpoint estimates of revenue, under different scenarios for the expected uptake of measures in the absence of further EU risk management policies.

Table 4.10 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				
All strictly non-BAU measures	€ 0 - 356,000	€ 1,514,000	€ 1,590,000	€ 1,686,000
Non-BAU measures except those likely to be applied already [1]	€ 0 - 342,000	€ 667,000	€ 729,000	€ 825,000
Non-BAU measures except those possibly applied already [2]	€ 0 - 298,000	€ 596,000	€ 654,000	€ 737,000
Annualised Costs as a Percentage of Expected Annual Revenues				
All strictly non-BAU measures	0.0 - 0.9%	3.6%	3.8%	4.1%
Non-BAU measures except those likely to be applied already [1]	0.0 - 0.8%	1.6%	1.8%	2.0%
Non-BAU measures except those possibly applied already [2]	0.0 - 0.7%	1.4%	1.6%	1.8%

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 and hence could theoretically be zero for operators. Consequently impact on revenues could be nil;
- Indications from the unconventional gas industry in Europe 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;

[43] 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).

- However, 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 (see above);

  - 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 each of the individual measures that comprise each policy option.

4.10 The Justification for Action at EU level: Subsidiarity

The Treaty (TFEU) enshrines the principle of subsidiarity into the functioning and rule-making of the EU. Subsidiarity is interpreted as meaning that decisions should be taken at the governance level which is most appropriate for those decisions to be effective – whether at EU, Member State, regional or local level. There are a number of reasons why actions should be taken at EU level. These are:

- *Functioning of the single market*: While, the primary justification for EU intervention in this regard is to ensure that the trading of goods and services within the single market is not impeded by rules or practices adopted by individual Member States (which is not an issue with unconventional gas extraction), EU level rules may also be adopted to deliver common standards of approach to environmental protection to ensure that businesses in some Member States do not have a competitive advantage over businesses in other Member States where such environmental protection rules do not apply;

- *Effective application of EU funds*: This is unlikely to be an issue with unconventional gas;

- *Protection of the shared environment*: The TFEU recognises the necessity of environmental protection and the justification of EU-level action to ensure that environmental resources considered to be of importance to European citizens are protected;

- *Increased efficiency*: EU-level action may be justified where adoption of EU-level rules of systems may be more efficient that a multiplicity of rules or systems developed at Member State level. The increase in efficiency may either be due simply to economies of scale or also due to avoidance of divergent systems between Member States which impede business activities across the Union or impose additional costs to business; and

- *Sharing of knowledge*: Member States benefit from sharing of knowledge and experience. This may include environmental data, models, tools, best management practice, etc. EU-level action could be justified to assist in the sharing and dissemination of such knowledge to help Member States meet their obligations under EU law and/or national environmental priorities.

It is important to note that these justifications for action at EU level do not necessarily imply legislative action or prescribe obligations on Member States. Rules deemed to be necessary to ensure functioning of the single market would likely involve legislative obligations on Member States. However, sharing of knowledge, for example, could take the form of an enabling action which Member States contribute to on a voluntary basis.

With regard to unconventional gas extraction, there is a clear justification for EU level intervention. Member States are either interpreting existing EU law in different ways or establishing their own national rules on this activity and these also vary. Thus there is not a level playing field for the industrial sector. Furthermore, unconventional gas extraction poses a number of environmental risks which threaten the shared environment of the Union and, in particular, the objectives of existing EU environmental policy. The adoption of rules at EU level would overcome these barriers and concerns. Furthermore, such rules would reduce the need for rule development at Member State level and would, therefore, increase efficiency (along with regulatory certainty). The adoption of new EU rules and/or guidance would also stimulate information sharing between Member States and this would be beneficial to authorities, industry and stakeholders alike.

As a result, when considering the reasons set out in the TFEU for EU-level intervention, there is a clear case for this with regard to unconventional gas extraction. The appropriate nature of that intervention is the subject of the discussion of the options (see above).

5. Conclusions

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

5.1 Key Environmental Risks of Unconventional Gas

The principal risks presented that are specific to unconventional gas exploration and production such as shale gas can be summarised, by theme as follows:

- Underground contamination and seismicity aspects: particularly risks from well failure, introduction of pollutants due to induced fractures providing pathways to groundwater resources through either pre-existing man-made or natural structures, induced seismicity and the potential impact on well integrity, creation of geological pathways for pollutants and possible minor earth tremors;
- Chemicals usage: risks resulting from potential inappropriate selection of chemicals in hydraulic fracturing and/or unsuitable assessment leading to unacceptable risks to the environment from releases; lack of public/regulator scrutiny on specific chemicals used leading to unsuitable control of risks;
- Water depletion: extraction of groundwater or surface water for use in fracturing and the resulting risk of quality and quantity impacts on water resources;
- Surface water quality: the risk of pollution incidents stemming from spillage of wastewaters, muds or chemicals;
- Air quality: risks resulting from emissions from diesel engines providing power onsite, air pollutants released from the well, flowback or produced water (fugitive and/or flared and/or vented) and emissions from vehicles associated with haulage;
- Waste: risks resulting from flowback or produced water leading to pollution of surface water: due to lack of proper characterisation or treatment plant not being suitable to treat contaminants;
- Zoning and landtake: zoning i.e. risks resulting from well-pads located at unsuitable distances from aquifers, drinking water sources, residential areas, nature protection areas, etc. and landtake requirements (leading to a range of other environmental impacts/risks, with cumulative impacts potentially being significant); and
- Traffic: risks from the large numbers of vehicle movements associated with water supply and flowback and produced water transportation for treatment.

5.2 Problem Characterisation

Issues relevant to EU environmental law with regard to unconventional gas have been identified. These include:

- Although there are relevant requirements across the *acquis*, these are not in sufficient detail or specific enough to address all risks arising from unconventional gas exploration and production using the measures identified here;

- Permits under the Mining Waste Directive are limited in their capacity to address all aspects of unconventional gas operations as they focus on waste management; and

- The *acquis* does not fully address the underground environment, geological, hydrogeological and induced seismicity aspects of unconventional gas extraction.

At the Member State level[44]:

- There are legal uncertainties. For example, regulation may be primarily focussed on water, industrial and/or mining waste law (or a combination, requiring operators to have several permits). As a result requirements at national level are not only different, but sometimes contradictory;

- None of the Member States examined have a regulatory regime specifically for unconventional gas;

- An analysis of selected Member States has found that there is divergence in the regulation of unconventional gas extraction in Member States and also divergence in the interpretation of EU environmental law to address the challenges this type of facility places on regulators; and

- Regulatory uncertainties and gaps are prompting Member States to review legislation and draft new law. Divergence may continue and not all regulatory development at Member State level may deliver the necessary and required management of environmental impacts and risks, notably in the light of possible cross-border effects. Also developments at Member State level run the risk of providing a fragmented regulatory framework across the EU which could result in an uneven 'playing field' for business and increased business costs as individual companies adapt to different regulatory regimes.

Regarding best practice/voluntary actions by industry:

- Whilst best/recommended practice and voluntary approaches are emerging, they are not well established or fully integrated, particularly taking into account the early stage in development of certain unconventional gas resources such as shale gas in Europe. The industry across Europe may be aware of best practices but there remains no coherent industry approach or agreement to implement a recognised set of objectives or practices.

Regarding the need for action:

- Best practices may be able to address many of the main environmental risks presented by unconventional gas exploration and production but would need to be systematically applied by industry;

- A coherent and comprehensive approach is absent at EU level, in particular with regard to strategic planning, environmental impact assessment, integrated baseline reporting and monitoring requirements, capture of gases, well integrity, and public disclosure of chemicals used in each well;

[44] Based on the conclusions of the report 'Regulatory provisions governing key aspects of unconventional gas extraction in selected Member States' (Milieu, 1st July 2013) for the European Commission.

- There are gaps in the *acquis* in particular with regard to underground risks;
- The development of regulation at the Member State level runs the risk of a lack of a level playing field for business; and
- A response at EU level would help to address the cross-border dimension of unconventional gas and its environmental effects.

5.3 Measures to Address Risks

Over 200 potential non-BAU measures were identified. All of the measures were identified as addressing (partially or fully) specific identified environmental risks. Some of the measures could be applied in combination whilst others are alternatives, particularly where a different level of ambition of risk management is required.

In considering the wide range of measures, the following key measures (or groups of measures) can be defined (measures presented are key measures and this is not an exhaustive list (see Appendix C)):

- Zoning:
  - A range of measures addressing the zoning of unconventional gas to prevent or mitigate impacts on specific sensitive environments and land uses.
- Underground risks:
  - Establishment of geological, hydrogeological and seismic data and conceptual baseline model of the area under exploration;
  - Modelling of the fracture programme and requiring smaller pre-injection prior to main operations to enable induced seismicity response to be assessed;
  - Requirements for well safety and integrity testing; and
  - Monitoring of underground conditions (e.g. groundwater, seismicity) during exploration, production and following well closure.
- Chemicals:
  - The assessment of chemicals to be used in hydraulic fracturing, particularly explicit to hydraulic fracturing conditions and regarding potential transformation products and mixtures in the underground context;
  - The selection of chemicals based on negative/positive lists of chemicals, that reduce potential impacts on the environment once released, which minimise subsequent flowback treatment requirements or which result in only inert materials being used; and
  - The disclosure of chemical usage to competent authorities and the public.
- Water depletion:

- A range of measures addressing the development of demand profiles for water use, development of water management planning and reuse of wastewater to minimise demand.

- Surface water quality:

  - Key measures addressing surface water quality focus on pollution prevention through a variety of technical measures including provision of spill kits, site construction (e.g. berm around site, installation of impervious liner under the site), equipment (bunded tanks, level alarms) and monitoring of surface water bodies.

- Air quality:

  - A series of measures addressing emissions from on-site power generation through either fuel or power source substitution or emissions abatement; and

  - Reduced emissions completions to prevent/minimise releases from venting gas from the well and flowback and produced water through flaring and/or capture.

- Waste:

  - Key measures addressing waste are those focussed on monitoring flowback and produced water characteristics to enable appropriate treatment to be established and, secondly (and more fundamentally), the appropriate treatment of the wastewaters.

- Post closure:

  - Key measures are focussed on abandonment surveys for various parameters; inspections and maintenance; and requirements for retention of ownership and liability for damage, the transfer of responsibilities and financial guarantees/contributions from operators to cover costs of monitoring and remedial actions.

- Public acceptance:

  - Public acceptance measures focus on those for both operators and Competent Authorities. Key measures for operators centre on disclosure of information and engagement of the public. For Competent Authorities, measures focus on provision of information on licences/permits and other relevant information regarding unconventional gas.

- Other measures:

  - ‘Other’ measures cover a wide range of aspects such as incident response (contingency planning emergency response), assurance and delivery (including development of the capacity of Member State competent authorities), noise management and mitigation, environmental permitting and assessment and transportation measures.

5.4 Policy Options to Deliver Measures

Policy options were first considered in broad terms and then potential options with specific combinations of measures were selected by the Commission for more detailed assessment. Measures were developed following a review of risks and the application of the *acquis communautaire* to establish whether or not the identified measures were required. Measures that were considered non-BAU were identified and associated costs and benefits evaluated (either qualitatively or quantitatively). Consideration was given to non-BAU measures that might be adopted by operators regardless of EU legislation (e.g. due to standard industry practice, or to minimise financial risk of investments) by assuming uptake rates of such measures and making necessary cost adjustments (refer to 4.8.7 for further detail).

It is not the purpose of this project to propose a particular option. However, it is clear that the current state of play (baseline option) would not ensure that all risks are addressed and would leave a fragmented regulatory landscape across the EU. The other options considered could all address the risks from unconventional gas to different extents. Legal amendment of existing legislation for example, could fully address some risks but not all, while voluntary approaches and guidance/recommendation can encompass all risks, but cannot guarantee practical application on the ground. A dedicated instrument would, however, be able to achieve this.

For the policy options selected for detailed analysis[45], the pros and cons of each option can be summarised as follows:

- All of the options can take forward a large number of measures, but legislative change is necessary to deliver some critical measures and Option C and D would be able to deliver more measures than Option B;
- Option D sets measures in a different regulatory context than option C (their uptake is more likely because the policy option includes specific detailed obligations);
- Option A can be adopted faster relative to other options and can theoretically take forward a number of measures, but its non-binding character means that there is no guarantee that these will be implemented. Option A cannot, therefore, guarantee that the necessary environmental and health protection is delivered;
- Option A furthermore cannot guarantee that a level playing field is developed across the EU for unconventional gas exploration and production;
- Option B would take many years to be fully implemented due to the piecemeal approach, presenting major problems for legislators, regulators and operators both to ensure full delivery of the necessary amendments and uncertainties as the regulatory environment is subject to repeated changes. In contrast, Option C or D could be fully adopted in a shorter timetable;
- Options B, C and D retain benefits from guidance and sharing best practice where these would be effective instruments;

45 Option A: to take forward guidance 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 goals and general principles) and accompany this with guidance; and Option D: to adopt a new dedicated legal instrument setting specific detailed obligations, in the form of a Regulation, and accompany this with guidance, see Section 4.8 for descriptions.

- There is an urgency to address issues of risk management of unconventional gas exploration and production and only Option A, C and D can be taken forward within a timetable that can address these needs; and
- Where Option B is attractive in providing necessary amendments to existing law, such amendments can be introduced within Option C and D, and for some Directives, would be implemented at a much earlier date than Option B.

Wherever possible, the costs of the identified risk mitigation measures were determined[46]. Costs of the options were then established by selection of relevant measures applicable under each option. 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:[47]
  - Option A. Recommendation plus Guidance: €0 to €1,512,000;
  - Option B. Amendment to the *Acquis* plus Guidance: €1,512,000;
  - Option C. Dedicated Legislation (a directive) plus Guidance: €1,578,000; and
  - Option D. Dedicated Legislation (a regulation) plus Guidance: €1,674,000.

  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 of Options by up to 60% 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: [48]

  - Option A. Recommendation plus Guidance: €0 to €595,000;
  - Option B. Amendment to the *Acquis* plus Guidance: €595,000;
  - Option C. Dedicated Legislation (a directive) plus Guidance: €643,000; and
  - Option D. Dedicated Legislation (a regulation) plus Guidance: €727,000.

  It should be noted that it was not possible to quantify some important and potentially costly measures (e.g. implementation of remedial measures if a well failure occurs) thus overall costs could be higher.

[46] Refer to Section 3 for a full description of the approach and measures.

[47] Refer to Table 4.5 for notes on policy option cost ranges.

[48] Refer to Table 4.6 for notes on policy option cost ranges.

- Regarding administrative costs for Option C, for a single site, total start-up costs for exploration and production would be €23,000 for an operator and €11,000 for the authorities. Annual recurring costs for monitoring, reporting and compliance checking would be around €6,000 for operators and €1,600 for the authorities for each well pad. Administrative costs for Option D are likely to be similar.

  An unconventional gas concession would have many pads (the illustrative concession assumes 250 sites per concession) and these would progressively be taken forward over many years so there would be efficiencies in permit development drawing on data from earlier site applications and operation;

  The estimated administrative cost associated with a permitting regime through a dedicated instrument would not be net cost as it would replace/combine elements of existing permits; and

- Administrative costs associated with amendments to the *acquis* would not remove the requirement for an operator to obtain several permits under the existing regulatory framework, hence Option B would not address these administrative burdens as effectively as Option C and D.

Appendix A
Glossary

Term	Definition
Acquis communautaire / '*acquis*'	The rights and obligations that EU countries share. Includes all EU' treaties and laws, declarations and resolutions, international agreements on EU affairs and the judgments given by the Court of Justice. Candidate countries have to accept the *'acquis'* before they can join the EU, and make EU law part of their own national legislation.
BAT / BREFs	BREF or BAT (Best Available Techniques) reference document' means a document, resulting from the exchange of information organised pursuant to Article 13 of the Industrial Emissions Directive. BREFs are drawn up for defined activities within a particular sector and describe, in particular, applied techniques, present emissions and consumption levels, techniques considered for the determination of best available techniques as well as BAT conclusions and any emerging techniques.
BOD	Biochemical oxygen demand; a measure of the amount of oxygen that bacteria will consume while decomposing organic matter.
BTEX,	Benzene, toluene, ethyl benzene, and xylene chemicals used mainly in producing petroleum products.
Drilling fluids / drilling mud	Fluid or lubricant added to the wellbore to facilitate the drilling process by suspending cuttings or controlling pressure for example.
Flowback water	Water and excess proppant typically mixed with residuals of chemicals and naturally occurring material (e.g. heavy metals, naturally occurring radioactive material depending on the geology) that flow back up to the surface after the hydraulic fracturing procedure is complete.
GWD	The Groundwater Directive. Directive 2006/118/EC on the protection of groundwater against pollution and deterioration.
H_2S	Hydrogen sulphide (a colourless, toxic, highly flammable gas).
HVHF	High Volume Hydraulic Fracturing.
IED	Industrial Emissions Directive. Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control)
IPPCD	Integrated Pollution Prevention and Control Directive. Directive 2008/1/EC concerning integrated pollution prevention and control
Mcm	Million cubic metres
MWD	Mining Waste Directive. Directive 2006/21/EC on the management of waste from extractive industries and amending Directive 2004/35/EC
NORM	Natural Occurring Radioactive Material.
Produced water	Fluids that return from the well along with the natural gas after fracturing has taken place. Such fluids can contain substances that are found in the formation, and may include dissolved solids (e.g. salt), gases (e.g. methane, ethane), trace metals, naturally occurring radioactive elements (e.g. radium, uranium), and organic compounds, as well as residual fracturing fluid.
Proppant	Solid material, typically treated sand or man-made ceramic materials, designed to keep an induced hydraulic fracture open.
SEAD	Strategic Environmental Impact Assessment Directive. Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment
(S)VOCs,	(Semi) Volatile organic compounds.

Term	Definition
TDS	Total dissolved solids.
UKOOG	United Kingdom Onshore Operators Group, the representative body for the UK onshore oil and gas industry.
WFD	Water Framework Directive. Directive 2000/60/EC establishing a framework for Community action in the field of water policy
Wire line logging	Continuous measurement of formation properties with electrically powered instruments to infer properties and make decisions about drilling and production.

Appendix B
Illustrative Concession

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 gas in Europe, the context of an *illustrative unconventional gas 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 gas 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 and information provided by the European Commission.

It should be noted that the characteristics of European unconventional gas development are not yet established and the literature available refers to specific conditions of unconventional gas development activities, mainly in North America. Expert judgement from project team members was used to adjust values from the North American examples to better reflect the European context.

Purpose of this Document

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

The details, including source references, of further parameters and units/unit ranges are provided in Table A.1. 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 3.

Summary of Illustrative Unconventional Gas Concession

Physical Infrastructure

A typical size of an unconventional gas concession would be 800 km^2, with approximately 250 multi-well pads within the area. A typical multi-well pad, containing eight well heads per pad, would require between 2.24 hectares at ground level during operation while covering approximately 320 hectares of underground gas formation. A typical horizontal well would be between 1,350 metres long and 3,000 metres deep (AEAT, 2012; JRC, 2013). The production lifetime of a well is 10 years, and refracturing rate is once during the lifetime (JRC, 2013).

Resource Requirements and Output Generation

For hydraulic fracturing, JRC (2013) suggests that a horizontal well would require 15,000 m^3 of fracture fluid and the well would be fractured twice during its lifetime (initial fracturing and one refracture). It is estimated that 90% of the fracturing fluid is water (i.e. 13,500 m^3), with proppant accounting for 9.5%[49]. Assuming density of 1.95 tonnes per m^3 for proppant, around 2,800 tonnes of proppants would be required per fracturing. Additives would account for 0.5% of the fracturing fluid and thus around 75 m^3 of additives would be required per fracture. Therefore required storage availability is approximately 13,500 m^3 for freshwater, 2,800 m^3 for proppant, and 75 m^3 for additives.

Well drilling, hydraulic fracturing, production of unconventional gas and well plugging/testing generate a significant volume of wastewater in the form of flowback, produced water and drilling mud. Literature suggests that there is significant uncertainty with regard to the proportion of the injected fracture fluid being returned as flowback water as well as the rate of produced water generation. For the illustrative concession, it was assumed that approximately 50% of the fracturing fluid would be returned as a flowback and some 35% of flowback is assumed to be recycled for further fracturing (JRC, 2013). Proportions of water, proppant and additives are assumed to be similar in flowback water.

Types of pollutants likely to be present in wastewater include VOCs, metals, petroleum hydrocarbons, NORM, oil and grease, BTEX, SVOCs, TDS, pH, sulphates, H_2S, heavy metals, biocides, emulsion breakers and corrosion inhibitors. Salinity of produced water would range from 5,000 to 200,000 ppm.

Each well would also require 1,500 to 3,000 kW of energy during drilling and fracturing. Typically, electricity is generated from (temporarily installed) diesel-run generators.

Table B1 Illustrative Concession Data

Parameter		Type	Value	Unit	Notes	Reference
1	Length of horizontal well	Physical	1,350	metres		AEAT (2012)
2	Depth of vertical well	Physical	3,000	metres		JRC (2013)
3	Area (overground) covered by well pad during construction	Physical	6	hectares		JRC (2013)
4	Area (overground) covered by well pad during operation	Physical	2.24	hectares		JRC (2013)
5	Area (underground = shale gas formation) covered by well pad	Physical	320	hectares		JRC (2013)

[49] Note that this is a conservative assumption. The overall share of chemical additives varies depending on the geological conditions and typically ranges from 0,5 to 2 % of the total fracturing fluid.

Parameter		Type	Value	Unit	Notes	Reference
6	Area per concession	Physical	800	km^2	Assumed gas saturation of entire area	Based on data from MSs and provided by EC
7	# of well pad sites per concession	Physical	250	units	Based on pad area and concession size	Data provided by the European Commission
8	Distance between well pad sites	Physical	1.5	km		JRC (2013)
9	Area occupied by well installations	Physical	0.7%	% of the land area (concession)	Based on pad size and area of concession	Data provided by the European Commission
10	# of well heads per well pad	Physical	8	units per well pad		JRC (2013)
11	Vertical drilling per day	Physical	110	metres / day		JRC (2013)
12	Horizontal drilling per day	Physical	55	metres / day	Horizontal drilling takes twice longer than vertical	JRC (2013)
13	Days required for vertical drilling	Time	27	days / well	Depth of well divided by drilling length per day	Data provided by the European Commission
14	Days required for horizontal drilling	Time	25	days / well	Depth of well divided by drilling length per day	Data provided by the European Commission
15	Duration of the drilling stage	Time	52	days / well	Sum of days required for vertical drilling and horizontal drilling	Data provided by the European Commission
16	Rate of mud generation from drilling	Waste	0.47 to 0.63	m^3 per metre drilled	Original assumptions: 0.9 to 1.2 barrels of mud generated per foot drilled. Converted to metric units	AMEC expert knowledge based on shale gas development sites in North America
17	Mud generated from drilling	Waste	1,650	m^3	Calculated from depth of well drilled and rate of mud generation (average used)	
18	Number of fractures per well during lifetime	Physical	2	times	One initial and one refracture.	JRC (2013)
19	Required vol. of fracture fluid per fracture	Resource	15,000	m^3		JRC (2013)
20	% Flowback of fracture fluid per fracture	Waste	50	%		JRC (2013)
21	Flowback from fracture fluid (volume) per fracture	Waste	7,500	m^3 per fracture	Based on volume of fracture fluid used and % flowback	JRC (2013)
22	Flowback of fracture fluid (volume) per well lifetime	Waste	15,000	m^3 per well	Based on volume of flowback and number of fractures per well lifetime	JRC (2013)
23	% Flowback recycle rate	Waste	35	%		JRC (2013)

	Parameter	Type	Value	Unit	Notes	Reference
24	Volume of recycled fracture fluid, to be used for further fracturing (volume) per well lifetime	Waste	5,250	m^3 per well	Based on volume of flowback fluid used and % recycling	
25	% Fracture fluid - water content	Resource	90	% of total volume		API (2010)
26	Volume of water (fresh or recycled) in fracture fluid per fracturing	Resource	13,500	m^3 per fracturing	Based on volume of fracture fluid and proportion of water in fracture fluid	
27	Water use in fracturing per well lifetime	Resource	24,750	m^3 per well		JRC (2013)
28	Proppant content in fracture fluid	Resource	9.50%	%		API (2010)
29	Density of proppant	Resource	1.95	tonnes/m^3	Assumed to be equal to density of wet sand	EC
30	Quantity of proppant in fracture fluid per fracture	Resource	2,779	tonnes	Based on volume of fracture fluid, proportion of proppant in fracture fluid and density of proppant	
31	Quantity of proppant in fracture fluid per well lifetime	Resource	5,558	tonnes	Based on volume of proppant and number of fractures during well lifetime	
32	% Fracture fluid - additives	Resource	0.50	% of total volume		API (2010)
33	Volume of additives in fracture fluid per fracture	Resource	75	m^3	Based on volume of fracture fluid and proportion of additives in fracture fluid	
34	Volume of additives in fracture fluid per well lifetime	Resource	150	m^3	Based on volume of additives and number of fractures during well lifetime	
35	Required water storage availability	Resource	15,000	m^3		JRC (2013)
36	Required proppant storage availability	Resource	2,779	tonnes	Equivalent to required volume for one fracture	
37	Required additive storage availability	Resource	75	m^3	Equivalent to required volume for one fracture	
38	Storage capacity per truck	Resource	40	m^3		AEAT (2012)
39	# of truck movements to manage freshwater for two hydraulic fractures	Resource	619	trucks	Based on required water divided by storage capacity per truck	
40	# of truck movements to manage flowback for two hydraulic fractures	Resource	244	trucks		AEAT (2012)
41	# of site construction truck movements	Resource	135	trucks	Assume 10 t truck. Duration four weeks	AEAT (2012)
42	# drilling stage truck movements	Resource	515	trucks	Assume 10 t truck. Duration 4 weeks, extending to 5 months for multiple wellheads	AEAT (2012)
43	Salinity of produced water	Waste	5,000-200,000	ppm		AEAT (2012)

Parameter		Type	Value	Unit	Notes	Reference
44	Types and levels of contaminants in flowback water	Waste	See note		See Table in source reference for information on contaminants	Table 2 of AEAT (2012)
45	Gas production (URR)	Output	56-185	mcm per well	Based on 30 year lifetime. Not used in calculation of costs for measures	JRC (2013)
46	Re-fracturing (occurrence)	Time	1	over a 10 year period		AEAT (2012)
47	Well lifetime	Time	10	years		JRC (2013)
48	Fuel/energy demand	Resource	1,500-3,000	kW	Drilling and fracturing operations	AMEC expert knowledge based on development sites in North America

The following monitoring is assumed to be carried out for the illustrative concession (for details of measures and costs, refer to Appendix D):

- 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.

Appendix C
Measures by Theme

This appendix presents the measures by 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).

Information is presented regarding:

- Measure theme categorisation;
- Measure reference;
- Measure description and sub-measure description;
- Further definition (where necessary, full information is presented in Appendix D);
- Where the measure information has been developed quantitatively or qualitatively;
- The Level of Ambition rating (see section 3.1.2);
- The stages to which the measure applies; and
- Whether or not the non-BAU measure is likely to be applied (i.e. under normal practice).

Non-BAU Measures Categorisation Zoning

16 Measures in total

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Zoning	N/A	42b	42b	Location of sites close to existing pipeline infrastructure		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	1	0	0	0	0	No
Zoning	N/A	N48	N48	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers and the surface to be determined based on risk assessment			Qual	MM	1	1	0	0	0	No
Zoning	N/A	26c	26c	Fracturing to be a minimum distance from water resources			Qual	MM	0	1	1	0	0	No
Zoning	N/A	40c	40c	High land, agricultural and ecological value locations avoided		Assessment of and avoidance of high land, agricultural and ecological value locations (e.g. Natura 2000 sites, conservation sites).	Qual	MM	1	0	0	0	0	No
Zoning	N/A	2f	2f	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells 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	1	0	0	0	0	No
Zoning	N/A	2f	2f	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells 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		Qual	MM	1	0	0	0	0	No
Zoning	N/A	2f	2f	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells and other potential pathways for fluid migration, and other sensitive areas	Buffer zone within which detailed noise assessment is required of 305m		Qual	MM	1	0	0	0	0	No
Zoning	N/A	2f	2f	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells 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)		Qual	MM	1	0	0	0	0	No
Zoning	N/A	2f	2f	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells 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	1	0	0	0	0	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Zoning	N/A	40a	40a	Optimisation from an environmental perspective, i.e. the number of wells, pad density and pad spacing		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 adequately implemented by Member States.	Qual	HM	1	0	0	0	0	No
Zoning	N/A	40b	40b	Compatibility with current and future potential landuse (Natura 2000 sites, conservation sites, human use, industrial use, appropriate zoning, CCS, geothermal, water abstraction)		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 excepted.	Qual	HM	1	0	0	0	0	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Zoning	N/A	1b	1b	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		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 or mining activities)	Qual	HM	1	0	0	0	0	Yes
Zoning	N/A	55e	55e	Avoid high seismicity risk areas			Qual	HH	1	0	0	0	0	No
Zoning	N/A	55i	55i	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		Qual	HH	0	1	0	0	0	No
Zoning	N/A	55i	55i	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		Qual	HH	0	1	0	0	0	No
Zoning	N/A	1a	1a	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		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	1	0	0	0	0	Yes

Non-BAU Measures Categorisation Underground Risks

42 Measures in total

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Underground Risks	N/A	N44	N44	Competent authorities compile regional maps of underground resources			Qual	LL	1	1	1	1	1	No
Underground Risks	N/A	N55	N55	Conduct 2D seismic survey to identify faults and fractures			Quant	LM	1	1	1	0	0	Yes
Underground Risks	N/A	28d	28d	Sharing of information to ensure that all operators in a gas play are aware of risks and can therefore plan			Qual	LM	1	0	0	0	0	Possible - low
Underground Risks	N/A	N45	N45	Members States establish a capability to address groundwater contamination arising from unconventional gas operations. In the case of transboundary aquifers, joint capability established			Qual	LM	1	1	1	1	1	No
Underground Risks	N/A	55g	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)			Qual	ML	1	1	0	0	0	Possible - low
Underground Risks	N/A	22d	22d	Search for and document potential leakage pathways (e.g. other wells, faults, mines)		Through delivery of 3 a x detail	Quant	MM	1	0	0	0	0	Possible - high
Underground Risks	N/A	26d	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)	Through delivery of 3 a x detail	Quant	MM	1	0	0	0	0	No
Underground Risks	N/A	26e	26e	Modelling of fracturing programme to predict extent of fracture growth based on best information		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	1	1	1	0	0	No
Underground Risks	N/A	26g	26g	Implementation of remedial measures if well failure occurs			Qual	MM	0	1	1	1	1	Yes
Underground Risks	N/A	55c	55c	Ground motion prediction models to assess the potential impact of induced earthquakes			Quant	MM	1	1	0	0	0	No
Underground Risks	N/A	N09	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)			Quant	MM	1	1	1	0	0	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Underground Risks	N/A	N05	N05	Initiate immediate flowback post fracturing			Qual	MM	0	1	1	0	0	No
Underground Risks	N/A	N46	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			Qual	MH	1	1	1	1	1	No
Underground Risks	N/A	N07	N07	Operator to use alternative fracturing fluids to water (e.g. nitrogen, CO2, propane)			Qual	MH	0	1	1	0	0	No
Underground Risks	N/A	55h	55h	Smaller preinjection prior to main operations to enable induced seismicity response to be assessed		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	0	1	0	0	0	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Underground Risks	N/A	22a	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		Measures to be split out for cost purposes	Quant	HH	0	1	1	0	0	Yes
Underground Risks	N/A	22b	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)		Quant	HH	0	1	1	1	0	Yes

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Underground Risks	N/A	22b	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		Quant	HH	0	1	1	1	0	Yes
Underground Risks	N/A	22b	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)		Quant	HH	0	1	1	1	0	Yes
Underground Risks	N/A	22b	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		Quant	HH	0	1	1	1	0	Yes
Underground Risks	N/A	22c	22c	Multiple barriers between the target formation and people/the environment, including minimum vertical distance between target formation and aquifers			Qual	HH	1	1	0	0	0	No
Underground Risks	N/A	26f	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		Linked to 3 b xvii	Quant	HH	0	1	1	0	0	No
Underground Risks	N/A	3a	3a xi	Site baseline Establish the presence of methane in groundwater, including drinking water			Quant	MM	1	0	0	0	0	Yes

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	**Sub**	**Measure ref.**		**Measure**	**Sub-measure description**	**Further definition**	**Quant/qual**	**LoA rating**	1	2	3	4	5	
Underground Risks	N/A	55d	55d	Microseismicity monitoring and management requirements during operations	LOW AMBITION Real time monitoring of microseismicity during all operations	Linked to 3 b xvii	Quant	MM	0	1	1	0	0	No
Underground Risks	N/A		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)		Qual	HH	0	1	1	0	0	No
Underground Risks	N/A	3a	3a iii	Site baseline Undertake sampling of groundwater	LOW 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	1	0	0	0	0	Yes
Underground Risks	N/A		3a iii	Site baseline Undertake sampling of groundwater	HIGH AMIBITION Borehole to sample deep groundwater and characterise the hydrological series	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	1	0	0	0	0	Possible - low
Underground Risks	N/A	3a	3a x-a1	Site baseline Geological, hydrogeological and seismic conceptual model [1] Obtain and analyze seismic (earthquake) history			Quant	HH	1	0	0	0	0	No
Underground Risks	N/A	3a	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		Quant	MH	1	0	0	0	0	Yes

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Underground Risks	N/A	3a	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.		Quant	HH	1	0	0	0	0	No
Underground Risks	N/A	3a	3a x-a3	Site baseline Geological, hydrogeological and seismic conceptual model [3] Undertake surface microseismic survey			Quant	HH	1	0	0	0	0	No
Underground Risks	N/A	3a	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		Quant	MH	1	0	0	0	0	No
Underground Risks	N/A	3a	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		Quant	HH	1	0	0	0	0	No
Underground Risks	N/A	3a	3a x-a5	Site baseline Geological, hydrogeological and seismic conceptual model [5] Develop maps and cross sections of local geologic structure			Quant	HH	1	0	0	0	0	Possible - low
Underground Risks	N/A	3a	3a x-a6	Site baseline Geological, hydrogeological and seismic conceptual model [6] Conduct 3D seismic survey to identify faults and fractures			Quant	HH	1	0	0	0	0	Possible - low
Underground Risks	N/A	3a	3a x-a7	Site baseline Geological, hydrogeological and seismic conceptual model [7] Obtain data on area, thickness, capacity, porosity and permeability of formations.			Quant	HH	1	0	0	0	0	Possible - high
Underground Risks	N/A	3a	3a xiii	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	1	0	0	0	0	Possible - high
Underground Risks	N/A	3a	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		Quant	HH	1	0	0	0	0	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Underground Risks	N/A	3b	3b iii	Monitoring Undertake monitoring of groundwater	LOW 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	0	1	1	1	0	Yes
Underground Risks	N/A	3b	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	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	0	1	1	1	0	No
Underground Risks	N/A	3b	3b xvii	Monitoring Undertake monitoring of induced seismicity from fracturing			Quant	HH	0	1	1	1	0	No
Underground Risks	N/A	3b	3b xviii	Monitoring Undertake monitoring for presence of methane seepages in groundwater, including drinking water.			Quant	HH	0	1	1	1	0	Possible - low

Non-BAU Measures Categorisation   Chemical Use   31   Measures in total

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Chemical Use	N/A	CSL5	CSL5	Authorities to organise an exchange of views/information on environmentally safer technologies and alternatives to the use of chemicals in hydraulic fracturing			Qual	LL	1	1	1	1	1	No
Chemical Use	N/A	N24	N24	Traceability of chemicals used by an operator			Qual	LL	0	1	1	0	0	No
Chemical Use	N/A	CAL1	CAL1	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	1	1	0	0	0	No
Chemical Use	N/A	CAL2	CAL2	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	1	1	1	0	0	No
Chemical Use	N/A	CAL3	CAL3	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	0	1	1	1	0	No
Chemical Use	N/A	CDL1	CDL1	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	1	1	1	1	1	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Chemical Use	N/A	CDL2	CDL2	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	1	1	1	1	1	Possible - high
Chemical Use	N/A	CSL1a	CSL1a	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		Qual	LM	0	1	1	0	0	No
Chemical Use	N/A	CSL1b	CSL1b	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		Qual	LM	0	1	1	0	0	No
Chemical Use	N/A	CSL1c	CSL1c	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as aquatic acute category 1 or aquatic chronic category 1	Chemicals - selection		Qual	LM	0	1	1	0	0	No
Chemical Use	N/A	CSL1d	CSL1d	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		Qual	LM	0	1	1	0	0	No
Chemical Use	N/A	CSL2	CSL2	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	1	1	1	0	0	No
Chemical Use	N/A	CSL3	CSL3	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	1	1	1	0	0	No
Chemical Use	N/A	CSL4	CSL4	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	0	1	1	0	0	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Chemical Use	N/A	CSM4	CSM4	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		Qual	LM	0	1	1	0	0	No
Chemical Use	N/A	CAM1	CAM1	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	1	1	1	1	0	No
Chemical Use	N/A	CSM2	CSM2	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	1	1	1	0	0	No
Chemical Use	N/A	CSM3	CSM3	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	1	1	1	0	0	No
Chemical Use	N/A	3b	3b x	Monitoring Undertake monitoring of chemicals type and volume used including record keeping			Quant	MM	0	1	1	1	0	Possible - low
Chemical Use	N/A	CSM1a	CSM1a	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	0	1	1	0	0	No
Chemical Use	N/A	CSM1b	CSM1b	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	0	1	1	0	0	No
Chemical Use	N/A	CSM1c	CSM1c	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	0	1	1	0	0	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Chemical Use	N/A	CSM1d	CSM1d	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	0	1	1	0	0	No
Chemical Use	N/A	CDM1	CDM1	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	1	1	1	1	1	Possible - high
Chemical Use	N/A	CDM2	CDM2	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	1	1	1	1	1	No
Chemical Use	N/A	N26	N26	Select proppants which minimise the HVHF treatment required			Qual	MH	0	1	1	0	0	No
Chemical Use	N/A	CAH1	CAH1	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	1	1	1	1	0	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Chemical Use	N/A	CDH1	CDH1	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	1	1	1	1	1	Possible - low
Chemical Use	N/A	CSH2a	CSH2a	Non-use of any (non-biocidal) substances with [harmonised or notified] classification for any health or environmental effects	Chemicals - selection		Qual	MH	0	1	1	0	0	No
Chemical Use	N/A	CSH2b	CSH2b	Non-use in biocidal products of any substances with [harmonised or notified] classification for any health or environmental effects	Chemicals - selection		Qual	MH	0	1	1	0	0	No
Chemical Use	N/A	CSH1	CSH1	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	0	1	1	0	0	No

Non-BAU Measures Categorisation Water Depletion 9 Measures in total

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Water Depletion	N/A	38a	38a	Notification of water demand from fracturing operations to relevant water utilities and competent authorities		Inform relevant authorities (i.e. water utilities, environmental regulators, planning authorities) of water demand for the lifetime of the project.	Qual	LM	1	0	0	0	0	No
Water Depletion	N/A	38b	38b	Demand profile for water		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	0	1	0	0	0	Possible - high
Water Depletion	N/A	N49	N49	Strategic planning and staged approach of play development to avoid peaks in water demand			Qual	MM	0	1	1	0	0	No
Water Depletion	N/A	38c	38c	Water management plan		Develop a water management plan to cover water supply and efficient use on site.	Qual	MM	0	1	1	0	0	Possible - high
Water Depletion	N/A	3a	3a vi	Site baseline Establish water source availability and test for suitability		Locate water sources and identifying availability, water rights. Test water sources for suitability	Quant	MM	1	0	0	0	0	Possible - high
Water Depletion	N/A	3b	3b vi	Monitoring Water resources availability			Quant	MM	0	1	1		0	No
Water Depletion	N/A	3b	3b ix	Monitoring Undertake monitoring of water volumes and origin			Quant	MM	0	1	1		0	No
Water Depletion	N/A	38d	38d	Reuse of flowback and produced water for fracturing		Reuse flowback and/or produced water to make up fracture fluid.	Quant	MM	0	1	1	0	0	No
Water Depletion	N/A	38e	38e	Use of lower quality water for fracturing (e.g. non-potable ground / surface water, rainwater harvesting, saline aquifers, sea water, treated industrial waterwaters)		Use lower quality water (non-potable) to make up fracture fluid.	Qual	MM	0	1	1	0	0	No

Non-BAU Measures Categorisation Surface Water

14 Measures in total

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Surface Water	N/A	33i	33i	Good site security		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	0	1	1	0	0	Yes
Surface Water	N/A	29a	29a	Good practice construction / deconstruction practices, including design for well abandonment		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	0	1	0	1	0	Possible - high
Surface Water	N/A	33a	33a	Good site practice to prevention of leaks and spills			Qual	MM	0	1	1	0	0	Yes
Surface Water	N/A	33d	33d	Spill kits available for use			Quant	MM	0	1	1	0	0	Yes
Surface Water	N/A	3a	3a ii	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	1	0	0	0	0	Possible - low
Surface Water	N/A	3b	3b ii	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	0	1	1	1	0	Possible - high
Surface Water	N/A	3b	3b ii	Monitoring Undertake monitoring of surface water bodies in wet and dry periods	HIGH AMBITION AS LOW AMBITION with alert system promoting corrective action		Quant	MH	0	1	1	1	0	No
Surface Water	N/A	33e	33e	Berm around site boundary			Quant	HM	0	1	1	0	0	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Surface Water	N/A	33g	33g	Collection and control of surface runoff		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	0	1	1	1	0	Possible - high
Surface Water	N/A	29c	29c	Bunding of fuel tanks			Quant	HH	0	1	1	0	0	No
Surface Water	N/A	30d	30d	Use of closed tanks for mud storage			Quant	HH	0	1	0	0	0	Possible - low
Surface Water	N/A	33b	33b	Use of tank level alarms		For chemicals, fracturing fluid, muds and wastewaters. Activation triggers corrective action/contingency plan implementation.	Quant	HH	0	1	1	0	0	Possible - high
Surface Water	N/A	33c	33c	Use of double skinned closed storage tanks	High Ambition	For chemicals, fracturing fluid, muds and wastewaters	Quant	HH	0	1	1	0	0	No
Surface Water	N/A	33f	33f	Impervious site liner under pad with puncture proof underlay			Quant	HH	0	1	1	0	0	Yes

Non-BAU Measures Categorisation Air Quality

11 Measures in total

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Air Quality	N/A	59d	59d	Use of vehicles (water, chemicals, waste trucking) that meet minimum air emission standards e.g. EURO standards			Qual	LL	0	1	1	0	0	No
Air Quality	N/A	N54	N54	Encourage industry voluntary approach to reduce air pollutants and greenhouse gases			Qual	LM	0	1	1	0	0	No
Air Quality	N/A	16b	16b i	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	Low emission power supply (switching to LPG)		Quant	LM	0	1	1	0	0	No
Air Quality	N/A	16b	16b ii	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	Low emission power supply (switching to grid electricity)		Quant	LM	0	1	1	0	0	No
Air Quality	N/A	16d	16d	Application of abatement techniques to minimise emissions (assumed SCR for NOx and Diesel Particulate Filter (DPF) for PM).		SCR for NOx Diesel Particulate Filter (DPF) for PM	Quant	LM	0	1	1	0	0	No
Air Quality	N/A	17c	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	Capture gas from fracture fluid at exploration stage and flare or incinerate	Quant	MM	0	1	0	0	0	Yes
Air Quality	N/A	17c	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		Quant	MM	0	1	0	0	0	No
Air Quality	N/A	3a	3a i	Site baseline Undertake sampling of air quality		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	1	0	0	0	0	Possible - high
Air Quality	N/A	3b	3b i	Monitoring Undertake monitoring of air quality		On-going monitoring in the vicinity of a pad. Monitoring for combustion gasses (NOx, NO2, PM10 and also SO2, CO and VOCs).	Quant	MM	0	1	1		0	Possible - low

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Air Quality	N/A	16a	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		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 emissions	Quant	MH	0	1	1	0	0	No
Air Quality	N/A	17b	17b	Reduced emission completions to eliminate gas venting: prohibit venting of gas; capture and cleaning for use of gas released from fracture fluid and produced water		Capture and cleaning for use of gas released from fracture fluid and produced water	Quant	HH	0	1	1	0	0	No

Non-BAU Measures Categorisation Waste

15 Measures in total

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Waste	N/A	N47	N47	Operator demonstrates availability of appropriate wastewater treatment facilities			Qual	LL	1	1	1	0	0	No
Waste	N/A	36c	36c	Treatment requirements for wastewater and capability of treatment works to treat wastewater established			Qual	LL	0	1	1	0	0	Possible - high
Waste	N/A	27c	27cii	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		Qual	LL	0	1	1	0	0	Possible - high
Waste	N/A	N50	N50	Lined open ponds with safety net protecting biodiversity			Qual	ML	0	1	1	0	0	No
Waste	N/A	27c	27c i	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		Qual	MM	0	1	1	0	0	Possible - high
Waste	N/A	3b	3b xiii	Monitoring Undertake monitoring of drilling mud volumes and treatment		Analyse for VOCs, metals, total petroleum hydrocarbons, NORM.	Quant	MM	0	1	1		0	No
Waste	N/A	3b	3b xiv	Monitoring Undertake monitoring of flowback water return rate and characterise		Analyse for oil & grease, BTEX, VOCs, SVOCs, TDS, pH, sulphates, H2S, heavy metals, NORM, biocides, emulsion breakers, corrosion inhibitors.	Quant	MM	0	1	1		0	Possible - high
Waste	N/A	3b	3b xv	Monitoring Undertake monitoring (volume and characterisation) of produced water volume and treatment solution		Analyse for oil & grease, BTEX, VOCs, SVOCs, TDS, pH, sulphates, H2S, heavy metals, NORM, biocides, emulsion breakers, corrosion inhibitors.	Quant	MM	0	1	1		0	Possible - high
Waste	N/A	N53	N53	Consider wastewaters from unconventional gas operations as hazardous waste			Qual	MM	0	1	1	0	0	No
Waste	N/A	27f	27f	Operators keep records of all waste management operations and make them available for inspection (e.g. of flowback, produced water management)			Qual	LH		1	1			No
Waste	N/A	N51	N51	Consider wastewaters hazardous unless operator demonstrates otherwise			Qual	MH	0	1	1	0	0	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	**Sub**	**Measure ref.**		**Measure**	**Sub-measure description**	**Further definition**	**Quant/qual**	**LoA rating**	1	2	3	4	5	
Waste	N/A	N52	N52	Ban injection of wastewaters into geological formations for disposal			Qual	MH	0	1	1	0	0	No
Waste	N/A	30c	30c	Use of closed loop system to contain drilling mud		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 farmed, hauled off or injected down-hole.	Quant	HH	0	1	0	0	0	Possible - high

Non-BAU Measures Categorisation Post Closure 20 Measures in total

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Post Closure	N/A	N22	N22	Maintain records of well location and depth indefinitely			Qual	LL	0	0	0	1	1	Yes
Post Closure	N/A	N11	N11	Operator to provide financial guarantee to competent authority to cover costs of any remedial action following transfer of responsibility		Required following transfer of responsibility as prior to that point in time, the operator remains responsible for remedial action.	Qual	LM	0	0	0	0	1	No
Post Closure	N/A	N12	N12	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)			Qual	ML	0	0	0	0	1	No
Post Closure	N/A	26g	26g	Implementation of remedial measures if well failure occurs		Note - measure also listed under 'Underground risks'	Qual	MM	0	1	1	1	1	Possible - high
Post Closure	N/A	29a	29a	Good practice construction / deconstruction practices, including design for well abandonment		Note - also included in surface water ref. construction. Operators should apply construction industry good	Qual	MM	0	0	0	0	1	Possible - high
Post Closure	N/A	N10	N10	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]		Transfer of responsibility to occur	Qual	MM	0	0	0	1	1	No
Post Closure	N/A	13d	13d ii	Abandonment survey Undertake sampling of surface water bodies near the pad		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	0	0	0	0	1	Possible - high

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Post Closure	N/A	13d	13d iii	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	0	0	0	0	1	Possible - high
Post Closure	N/A	13d	13d iv	Abandonment survey Obtain data on drinking water abstraction points (wells, boreholes, springs, surface water abstraction points		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	0	0	0	0	1	Possible - high
Post Closure	N/A	13d	13d v	Abandonment survey Undertake land condition (soil) survey around pad		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	0	0	0	0	1	Possible - high
Post Closure	N/A	13d	13d vi	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	0	0	0	0	1	No
Post Closure	N/A	13d	13d vii	Abandonment survey Undertake sampling for methane near surface in the pad location			Quant	MM	0	0	0	0	1	No
Post Closure	N/A	13d	13d viii	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	0	0	0	0	1	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Post Closure	N/A	13d	13d viii	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	0	0	0	0	1	No
Post Closure	N/A	13d	13d ix	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	0	0	0	0	1	Possible - high
Post Closure	N/A	13d	13d ix	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	0	0	0	0	1	No
Post Closure	N/A	12	12	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)		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 cement to remain in ground.	Quant	HH				1		Possible - high

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	**Sub**	**Measure ref.**		**Measure**	**Sub-measure description**	**Further definition**	**Quant/qual**	**LoA rating**	1	2	3	4	5	
Post Closure	N/A	13b	13b i	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	0	0	0	0	1	Possible - high
Post Closure	N/A	13b	13b ii	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	0	0	0	0	1	Possible - high

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Post Closure	N/A	13c	13c	Ownership and liability of wells transferred to a competent authority on surrender of the site licence following a period of monitoring		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 well.	Qual	HH	0	0	0	0	1	No

Non-BAU Measures Categorisation Public Acceptance 8 Measures in total

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Public Acceptance	N/A	N23	N23	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		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	0	1	1	1	1	Possible - low
Public Acceptance	N/A	15	15ii	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) 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	1	1			1	Possible - high
Public Acceptance	N/A	N41	N41	Member State Competent Authorities provide information on the licences and permits of operators involved in unconventional gas exploration and production			Quant	LL	1	1	1	1	1	No
Public Acceptance	N/A	N42	N42	Prohibit non-disclosure agreements between local residents and/or landowners and unconventional gas operators			Qual	LL	1	1	1	1	1	No
Public Acceptance	N/A	N40	N40	Member State Competent Authorities provide a map of planned and existing exploration, production and abandoned well locations		Also relevant to underground potentially	Quant	MM	0	1	1	1	1	No
Public Acceptance	N/A	15	15i	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) 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	1	1	1	1	1	Possible - low

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Public Acceptance	N/A	N03	N03	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			Qual	MM	1	1	1	1	1	No
Public Acceptance	N/A	N04	N04	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			Qual	MM	1	1	1	1	1	No

Non-BAU Measures Categorisation Other Measures

64 Measures in total

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Other Measures	sea	N34	N34	Public authorities produce an underground regional impact assessment to optimise resource allocation between unconventional gas and other underground resources (e.g. geothermal energy)			Quant	LL	1	0	0	0	0	No
Other Measures	permit	N35	N35	Member States implement integrated permitting for unconventional gas			Qual	LL	1	1	1	0	0	No
Other Measures	N/A	N25	N25	Reversal of the burden of proof for unconventional gas operators in the context of liability in case of environmental damage			Qual	LL	0	1	1	0	0	No
Other Measures	N/A	N38	N38	Maintain operator liability for any pollution arising from wells for a period of 100 years			Qual	LM	0	0	0	0	1	No
Other Measures	N/A	N39	N39	Maintain operator liability for any pollution arising from wells indefinitely			Qual	LM	0	0	0	0	1	No
Other Measures	operator	N28	N28	Assessment by the Competent Authority of the technical and financial capacity of an operator			Qual	LM	1	1	0	0	1	No
Other Measures	trans	59a	59a	Traffic impact assessment including consideration of noise, emissions and other relevant impacts			Quant	LM	0	1	0	0	0	Possible - high
Other Measures	operator	N29	N29	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)			Qual	LM	1	1	1	1	1	No
Other Measures	efficiency	N36	N36	Operators work together to ensure efficient provision of gas collection and wastewater treatment infrastructure			Qual	LM	1	1	1	0	0	No
Other Measures	ecology	N21	N21	Implement precautions to prevent invasive species by cleaning vehicles			Qual	ML	0	1	1	0	0	No
Other Measures	permit	N15	N15	Mandatory EIA for all projects expected to involve hydraulic fracturing, before exploration starts			Quant	ML	1	0	0	0	0	No
Other Measures	permit	N16	N16 i	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		Quant	ML	1	1	0	0	0	No
Other Measures	permit		N16 ii	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		Quant	ML	1	1	0	0	0	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Other Measures	permit	N17	N17	Assessment of whether full project is likely to have significant effects on the environment during prospecting phase (i.e. extending the existing requirement			Quant	ML	1	0	0	0	0	No
Other Measures	incident	N08	N08a	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.		Qual	ML	0	1	1	1	0	Possible - high
Other Measures	incident	N08	N08b	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.		Qual	ML	0	1	1	1	0	No
Other Measures	trans	59b	59b	Transport management plan (including consideration of available road, rail, waterway infrastructure)			Quant	MM	0	1	1	0	0	Possible - high
Other Measures	trans	60c	60c	Site selection close to water sources to minimise haulage requirements			Qual	MM	1	0	0	0	0	No
Other Measures	trans	61b	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.		Qual	MM	0	1	1	0	0	No
Other Measures	trans		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.		Qual	MM	0	1	1	0	0	No
Other Measures	trans	61c	61c	Site selection close to wastewater treatment / disposal facilities to minimise haulage requirements			Qual	MM	1	0	0	0	0	No
Other Measures	incident	N09	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)			Quant	MM	1	1	1	0	0	Possible - low
Other Measures	noi	51a	51a	Maximum noise levels specified			Qual	MM		0	1	1	0	Possible - high

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	**Sub**	**Measure ref.**		**Measure**	**Sub-measure description**	**Further definition**	**Quant/qual**	**LoA rating**	1	2	3	4	5	
Other Measures	noi	51c	51c	Noise screening installation: (i) screen drilling and fracturing rigs with noise barrier / enclosure; (ii) acoustic fencing around the site perimeter.		Screen drilling and fracturing rigs with noise barrier/enclosure. Acoustic fencing around the site perimeter.	Quant	MM		0	1	1	0	Possible - high
Other Measures	noi	51d	51d	Operational hours specified		(Noise abatement)	Qual	MM		0	1	1	0	Possible - low
Other Measures	noi	51e	51e	Vehicle routes specified		(Noise abatement)	Qual	MM		0	1	1	0	Possible - high
Other Measures	noi	51f	51f	Machinery orientation and selection to minimise noise		(Noise abatement)	Qual	MM		0	1	1	0	Possible - low
Other Measures	noi	3a	3a viii	Site baseline Undertake noise study		Consult with relevant regulatory authority and carry out baseline noise monitoring	Quant	MM	1	0	0	0	0	Possible - low
Other Measures	noi	3b	3b viii	Monitoring Undertake monitoring of noise			Quant	MM	0	1	1	1	0	Possible - low
Other Measures	monitor	N27	N27	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			Quant	MM	1	1	1	1	1	No
Other Measures	guidance	N30	N30	The European Commission to develop further criteria/guidance for the assessment of environmental impacts from unconventional gas			Quant	MM	1	1	1	1	1	No
Other Measures	inspection	N31	N31	Inspections by Competent Authorities during all stages of development (e.g. of well completion reports and environmental risk management and controls)			Quant	MM	0	1	1	1	1	Possible - high
Other Measures	skills	N32	N32	Competent Authorities have available sufficient inspection capacity and appropriately skilled inspectors			Qual	MM	1	1	1	1	1	No
Other Measures	inspection	N33	N33	Independent inspection during all stages of development of well integrity			Qual	MM	0	1	1	1	1	No
Other Measures	ecology	N37	N37	Pad construction activities staged to reduce soil erosion and to coincide with low rainfall periods			Qual	MM	1	1	0	0	0	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Other Measures	baseline	3a	3a iv	Site baseline Obtain data on drinking water abstraction points (wells, boreholes and springs)		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	1	0	0	0	0	Possible - high
Other Measures	trans	3a	3a v	Site baseline Undertake land condition (soil) survey around pad		Trial pits and analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, asbestos, chloride.	Quant	MM	1	0	0	0	0	Possible - high
Other Measures	trans	3a	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		Quant	MM	1	0	0	0	0	Possible - high
Other Measures	trans	3a	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		Quant	MM	1	0	0	0	0	Possible - low
Other Measures	ecology	3a	3a ix	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	1	0	0	0	0	Possible - low
Other Measures	baseline	3a	3a xii	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	1	0	0	0	0	Possible - high
Other Measures	baseline	3a	3a xii	Site baseline Undertake assessment of landuse, infrastructure and buildings	HIGH AMBITION. As LOW plus remote (aerial) survey of land, land uses, structures etc.		Quant	MM	1	0	0	0	0	No
Other Measures	monitor	3b	3b iv	Monitoring Undertake monitoring of drinking water abstraction points (wells, boreholes, springs, surface water)		Obtain water quality data and water gas content from existing available data. Ongoing monitoring. Annual desk study using data from abstraction points.	Quant	MM	0	1	1	1	0	Possible - high

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Other Measures	monitor	3b	3b v	Monitoring Undertake land condition (soil) tests every five years outside site boundary		Analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, chloride).	Quant	MM	0	1	1	1	0	No
Other Measures	trans	3b	3b vii	Monitoring Undertake monitoring of traffic numbers and patterns		Traffic count site/system to provide weekly or monthly counts.	Quant	MM	0	1	1	1	0	Possible - low
Other Measures	monitor	3b	3b xi	Monitoring Undertake monitoring of energy source and use			Quant	MM	0	1	1	1	0	No
Other Measures	monitor	3b	3b xii	Monitoring Undertake monitoring of greenhouse gas emissions			Quant	MM	0	1	1	1	0	No
Other Measures	ecology	3b	3b xvi	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	0	1	1	1	0	Possible - low
Other Measures	incident	3b	3b xix	Monitoring Undertake monitoring of spills volume, nature, location and clean-up (including reporting)			Quant	MM	0	1	1	1	0	Possible - high
Other Measures	cumulative	7	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		Complimentary with other measures associated with planning. Linked to SEA	Qual	MM	1	0	0	0	0	No
Other Measures	permit	N02	N02	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			Qual	MM	1	1	1	1	1	No
Other Measures	permit	N06	N06	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			Quant	MM	0	1	1	1	1	No

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Other Measures	sea	N13	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 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.			Quant	MM	1	1	1	1	1	No
Other Measures	equip	N18	N18	Ensure equipment is compatible with composition of fracturing chemicals			Qual	MM	0	1	1	0	0	Possible - high
Other Measures	equip	N19	N19	Carry out thorough planning and testing of equipment prior to hydraulic fracturing operations			Qual	MM	0	1	1	0	0	Possible - high
Other Measures	management	N20	N20	Environmental management system accreditation for unconventional gas installation operators			Quant	MM	1	1	1	1	0	No
Other Measures	materials	30e	30e	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	0	1	0	0	0	No
Other Measures	materials	30e	30e	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	0	1	0	0	0	No
Other Measures	management	29e	29e	Site reinstatement plan		Purpose of measure is to develop a reinstatement plan for the site following well closure and abandonment.	Quant	MH	0	0	0	1	0	Yes
Other Measures	incident	9b	9b	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			Qual	HM	0	1	1	1	0	Yes

Categorisation		Measure info							Stage					Non-BAU, but Likely to be applied?
Main	Sub	Measure ref.		Measure	Sub-measure description	Further definition	Quant/qual	LoA rating	1	2	3	4	5	
Other Measures	incident	9a	9a	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			Qual	HH	1	1	1	1	0	Possible - high
Other Measures	trans	60a	60a	Use of temporary surface pipes for distribution of water supply		Temporary pipes laid above ground to supply water to pads.	Qual	HH	0	1	1	0	0	No
Other Measures	trans	60b	60b	Use of temporary surface pipes for collection of flowback		Temporary pipes laid above ground to collect flowback and transport to treatment plant.	Qual	HH	0	1	1	0	0	No
Other Measures	trans	61a	61a	Use of temporary surface pipes for collection of produced water		Temporary pipes laid above ground to collect produced water and transport to treatment plant.	Qual	HH	0	1	1	0	0	No

Appendix D
Measure Datasheets

This appendix presents:

- A summary table of quantitative non-BAU measures;
- Datasheets for quantitative non-BAU measures;
- Inflation and exchange data utilised in the quantitative measures;
- Wage data utilised in the quantitative measures;
- A summary table of qualitative non-BAU measures; and
- Datasheets for qualitative non-BAU measures.

Non-BAU Measures - Quantitative Analysis

Item	Measures	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Amortisation period (years)	Annualised Compliance Cost (€ per pad)		
		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit	MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION
3a i	Baseline - air	5,800	5,800	5,800	per pad	-	-	-	per pad	Over the lifetime of the pad	715	715	715
3a ii	Baseline - surface water	N/A	6,600	28,000	per pad	-	-	-	per pad	Over the lifetime of the pad	2,133	814	3,452
3a iii	Baseline - groundwater	10,000	7,000	1,200,000	per pad	-	-	-	per pad	Over the lifetime of the pad	1,233	863	147,949
3a iv	Baseline - drinking water abstraction points	10,000	10,000	10,000	per pad	-	-	-	per pad	Over the lifetime of the pad	1,233	1,233	1,233
3a v	Baseline - land conditions (soil)	14,000	14,000	14,000	per pad	-	-	-	per pad	Over the lifetime of the pad	1,726	1,726	1,726
3a vi	Baseline - water resources availability and suitability	51,000	51,000	51,000	per pad	-	-	-	per pad	Over the lifetime of the pad	6,288	6,288	6,288
3a vii	Baseline - transport and traffic	N/A	5,000	37,000	per pad	-	-	-	per pad	Over the lifetime of the pad	2,589	616	4,562
3a viii	Baseline - noise	4,600	4,600	4,600	per pad	-	-	-	per pad	Over the lifetime of the pad	567	567	567
3a ix	Baseline - biodiversity/ecology/invasive species	N/A	41,000	65,000	per pad	-	-	-	per pad	Over the lifetime of the pad	6,534	5,055	8,014
3a x-a1	Baseline - geological, hydrogeological and seismic conceptual model: [1] obtain and analyse seismic (earthquake) history	3,500	3,500	3,500	per pad	-	-	-	per pad	Over the lifetime of the pad	432	432	432
3a x-a2	Baseline - geological, hydrogeological and seismic conceptual model: [2] Obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures	N/A	3,500	290,000	per pad	-	-	-	per pad	Over the lifetime of the pad	18,093	432	35,754
3a x-a3	Baseline -geological, hydrogeological and seismic conceptual model: [3] Undertake surface microseismic survey	39,000	39,000	39,000	per pad	-	-	-	per pad	Over the lifetime of the pad	4,808	4,808	4,808
3a x-a4	Baseline - geological, hydrogeological and seismic conceptual model: [4] Complex modelling of fluid flows and migration (reservoir simulations)	N/A	33,000	43,000	per pad	N/A	2,700	3,500	per pad	Over the lifetime of the pad	7,785	6,769	8,802
3a x-a5	Baseline - geological, hydrogeological and seismic conceptual model: [5] Develop maps and cross sections of local geologic structure	3,500	3,500	3,500	per pad	-	-	-	per pad	Over the lifetime of the pad	432	432	432
3a x-a6	Baseline - geological, hydrogeological and seismic conceptual model: [6] Conduct 3D seismic survey to identify faults and fractures	N/A	-	360,000	per pad	-	-	-	per pad	Over the lifetime of the pad	22,192	-	44,385
3a x-a7	Baseline - geological, hydrogeological and seismic conceptual model: [7] Obtain data on area, thickness, capacity, porosity and permeability of formations	1,400	1,400	1,400	per pad	-	-	-	per pad	Over the lifetime of the pad	173	173	173
3a xi	Baseline - presence of methane seepages in groundwater, including drinking water.	-	-	-	per pad	-	-	-	per pad	Over the lifetime of the pad	-	-	-
3a xii	Baseline - existing land use, infrastructure, buildings		1,800	4,300	per pad	-	-	-	per pad	Over the lifetime of the pad	376	222	530
3a xiii	Baseline - existing underground wells and structures		900	3,200	per pad	-	-	-	per pad	Over the lifetime of the pad	253	111	395
3b i	M&R - air	-	-	-	per pad	5,800	5,800	5,800	per pad	N/A	5,800	5,800	5,800
3b ii	M&R - surface water	N/A	-	5,000	per pad	2,000	2,000	2,000	per pad	N/A	2,308	2,000	2,616
3b iii	M&R - groundwater	N/A	11,000	-	per pad	N/A	-	11,000	per pad	N/A	6,178	1,356	11,000
3b iv	M&R - drinking water abstraction points	-	-	-	per pad	2,400	2,400	2,400	per pad	N/A	2,400	2,400	2,400
3b v	M&R - land conditions (soil)	-	-	-	per pad	400	400	400	per pad	N/A	400	400	400
3b vi	M&R - water resources availability	-	-	-	per pad	2,400	2,400	2,400	per pad	N/A	2,400	2,400	2,400

Non-BAU Measures - Quantitative Analysis

Item	Measures	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Amortisation period (years)	Annualised Compliance Cost (€ per pad)		
		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit	MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION
3b vii	M&R - traffic	-	-	-	per pad	3,100	3,100	3,100	per pad	N/A	3,100	3,100	3,100
3b viii	M&R - noise	-	-	-	per pad	11,000	11,000	11,000	per pad	N/A	11,000	11,000	11,000
3b ix	M&R water volumes and origin	-	-	-	per pad	2,000	2,000	2,000	per pad	N/A	2,000	2,000	2,000
3b x	M&R - chemicals nature and volume used (i.e. record keeping)	-	-	-	per pad	2,000	2,000	2,000	per pad	N/A	2,000	2,000	2,000
3b xi	M&R - energy source and use	-	-	-	per pad	2,000	2,000	2,000	per pad	N/A	2,000	2,000	2,000
3b xii	M&R - greenhouse gas emissions	-	-	-	per pad	2,000	2,000	2,000	per pad	N/A	2,000	2,000	2,000
3b xiii	M&R - drilling mud volumes and treatment	19,000	19,000	19,000	per pad	-	-	-	per pad	Over the lifetime of the pad	2,343	2,343	2,343
3b xiv	M&R - flowback water return rate	89,000	89,000	89,000	per pad	-	-	-	per pad	Over the lifetime of the pad	10,973	10,973	10,973
3b xv	M&R - produced water volume and treatment solution	-	-	-	per pad	47,000	47,000	47,000	per pad	N/A	47,000	47,000	47,000
3b xvi	M&R - biodiversity/ecology/invasive species	-	-	-	per pad	800	300	1,400	per pad	Variable	850	300	1,400
3b xvii	M&R - induced seismicity from fracturing	-	-	-	per pad	12,000	12,000	12,000	per pad	N/A	12,000	12,000	12,000
3b xviii	M&R - presence of methane seepages in groundwater, including drinking water.	-	-	-	per pad	-	-	-	per pad	N/A	-	-	-
3b xix	M&R - spills volume, nature, location and clean-up (includes reporting)	-	-	-	per pad	2,000	2,000	2,000	per pad	N/A	2,000	2,000	2,000
12	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)	413,000	413,000	413,000	per pad	-	-	-	per pad	Over the lifetime of the pad	50,919	50,919	50,919
13d i	Abandonment - air	-	-	-	-	-	-	-	-	Not Needed	-	-	-
13d ii	Abandonment - surface water	13,000	13,000	13,000	per pad	-	-	-	per pad	Over the lifetime of the pad	1,603	1,603	1,603
13d iii	Abandonment - groundwater	N/A	7,500	8,100	per pad	-	-	-	per pad	Over the lifetime of the pad	962	925	999
13d iv	Abandonment - drinking water abstraction points	6,500	6,500	6,500	per pad	-	-	-	per pad	Over the lifetime of the pad	801	801	801
13d v	Abandonment - land conditions (soil)	16,000	16,000	16,000	per pad	-	-	-	per pad	Over the lifetime of the pad	1,973	1,973	1,973
13d vi	Abandonment - biodiversity/ecology/invasive species	48,000	6,000	74,000	per pad	-	-	-	per pad	Over the lifetime of the pad	4,932	740	9,124
13d vii	Abandonment - presence of methane seepages	-	-	-	-	-	-	-	-	N/A	-	-	-
13d viii	Abandonment - existing landuse, infrastructure, buildings	N/A	3,500	6,300	per pad	-	-	-	per pad	Over the lifetime of the pad	604	432	777
13d ix	Abandonment - undertake assessment of ex-anti underground wells and structures	N/A	2,200	5,200	per pad	-	-	-	per pad	Over the lifetime of the pad	456	271	641
15i	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) permitting	N/A	11,000	32,000	per pad	N/A	-	2,000	per pad	Over the lifetime of the pad	3,651	1,356	5,945
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	31,000	31,000	31,000	per pad	-	-	-	per pad	Over the lifetime of the pad	3,822	3,822	3,822
16b i	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	-	-	-	per pad	48,000	48,000	48,000	per pad	5.00	48,000	48,000	48,000
16b ii	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	250,000	250,000	250,000	per pad	216,000	216,000	216,000	per pad	5.00	272,157	272,157	272,157

Non-BAU Measures - Quantitative Analysis

Item	Measures	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Amortisation period (years)	Annualised Compliance Cost (€ per pad)		
		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit	MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION
16d	Application of abatement techniques to minimise emissions (assumed SCR for NOx and Diesel Particulate Filter (DPF) for PM).	229,000	229,000	229,000	per pad	5,700	5,700	5,700	per pad	-	30,398	30,398	30,398
17b	Reduced emission completions to eliminate gas venting: prohibit venting of gas; capture and cleaning for use of gas released from fracture fluid and produced water	176,000	176,000	176,000	per pad	- 50,000	- 50,000	- 50,000	per pad	Over the lifetime of the pad	- 28,301	- 28,301	- 28,301
17c	Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network)	N/A	21,000	21,000	per pad	-	-	-	per pad	Over the lifetime of the pad	2,589	2,589	2,589
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)	7,000,000	7,000,000	7,000,000	per pad	-	-	-	per pad	Over the lifetime of pad	863,037	863,037	863,037
22a ii	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)	See qualitative assessment	-	-	-	See qualitative assessment	-	-	-	-	-	-	-
22a iii	casings: surface casing cemented before reaching a certain depth (e.g. 75m below as discussed in AEA 2012 report) underground drinking water	See qualitative assessment	-	-	-	See qualitative assessment	-	-	-	-	-	-	-
22a iv	casings: production casing cemented up to a certain distance (e.g. at least 150 metres as discussed in AEA 2012 report) above the formation where hydraulic fracturing will be carried out	See qualitative assessment	-	-	-	See qualitative assessment	-	-	-	-	-	-	-
22b i	Integrity testing at key stages in well development e.g. before/during/after all HF - wire line logging (calliper, cement bond, variable density)	25,000	25,000	25,000	per pad	2,000	2,000	2,000	per pad	Over the lifetime of the pad	5,082	5,082	5,082

Non-BAU Measures - Quantitative Analysis

Item	Measures	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Amortisation period (years)	Annualised Compliance Cost (€ per pad)		
		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit	MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION
22b ii	Integrity testing at key stages in well development e.g. before/during/after all HF - pressure (e.g. between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing	2,100	2,100	2,100	per pad	1,000	1,000	1,000	per pad	Over the lifetime of the pad	1,259	1,259	1,259
22b iii	Integrity testing at key stages in well development e.g. before/during/after all HF - mechanical integrity testing of equipment (MIT)	92,000	92,000	92,000	per pad	-	-	-	per pad	Over the lifetime of the pad	11,343	11,343	11,343
22b iv	Integrity testing at key stages in well development e.g. before/during/after all HF - Casing inspection test and log	350,000	350,000	350,000	per pad	-	-	-	per pad	Over the lifetime of the pad	43,152	43,152	43,152
22d	Search for and document potential leakage pathways (e.g. other wells, faults, mines)	-	-	-	per pad	-	-	-	per pad	N/A	-	-	-
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	-	-	-	per pad	N/A	3,300	4,300	per pad	Over the lifetime of pad	3,800	3,300	4,300
26e	Modelling of fracturing programme to predict extent of fracture growth based on best information	62,000	62,000	62,000	per pad	-	-	-	per pad	Over the lifetime of pad	7,644	7,644	7,644
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	-	-	-	per pad	10,000	10,000	10,000	per pad	N/A	10,000	10,000	10,000
29c	Bunding of fuel tanks	13,000	13,000	13,000	per pad	-	-	-	per pad	Over the lifetime of pad	1,603	1,603	1,603
29e	Site reinstatement plan	9,400	9,400	9,400	per pad	-	-	-	per pad	Over the lifetime of pad	1,159	1,159	1,159
30c	Use of closed loop system to contain drilling mud	160,000	160,000	160,000	per pad	Potential cost saving, see benefits.	-	-	per pad	Over the lifetime of pad	19,727	19,727	19,727
30d	Use of closed tanks for mud storage	27,000	27,000	27,000	per pad	-	-	-	per pad	Over the lifetime of pad	3,329	3,329	3,329
33b	Use of tank level alarms	26,000	26,000	26,000	per pad	-	-	-	per pad	Over the lifetime of pad	3,206	3,206	3,206
33c	Use of double skinned closed storage tanks	N/A	1,500	96,000	per pad	-	-	-	per pad	Over the lifetime of pad	6,010	185	11,836
33d	Spill kits available for use	4,000	4,000	4,000	per pad	-	-	-	per pad	Over the lifetime of pad	493	493	493
33e	Berm around site boundary	79,000	79,000	79,000	per pad	-	-	-	per pad	Over the lifetime of pad	9,740	9,740	9,740
33f	Impervious site liner under pad with puncture proof underlay	240,000	240,000	240,000	per pad	-	-	-	per pad	Over the lifetime of pad	29,590	29,590	29,590
33g	Collection and control of surface runoff	41,000	41,000	41,000	per pad	13,000	13,000	13,000	per pad	Over the lifetime of pad	18,055	18,055	18,055
33i	Good site security	40,000	40,000	40,000	per pad	14,000	14,000	14,000	per pad	Over the lifetime of pad	18,932	18,932	18,932
38b	Demand profile for water	13,000	13,000	13,000	per pad	-	-	-	per pad	Over lifetime of the pad	1,603	1,603	1,603
38d	Reuse of flowback and produced water for fracturing	5,000	5,000	5,000	per pad	-	-	-	per pad	Over lifetime of the pad	616	616	616

Non-BAU Measures - Quantitative Analysis

Item	Measures	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Amortisation period (years)	Annualised Compliance Cost (€ per pad)		
		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit	MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION
51c	Noise screening installation: (i) screen drilling and fracturing rigs with noise barrier / enclosure; (ii) acoustic fencing around the site perimeter.	219,000	219,000	219,000	per pad	13,400	13,400	13,400	per pad	Over lifetime of the pad	40,401	40,401	40,401
51c i	Noise screening installation: (i) screen drilling and fracturing rigs with noise barrier / enclosure; (ii) acoustic fencing around the site perimeter.	130,000	130,000	130,000	per pad	13,000	13,000	13,000	per pad	Over lifetime of the pad	29,028	29,028	29,028
51c ii	Noise screening installation: (i) screen drilling and fracturing rigs with noise barrier / enclosure; (ii) acoustic fencing around the site perimeter.	89,000	89,000	89,000	per pad	400	400	400	per pad	Over lifetime of the pad	11,373	11,373	11,373
55c	Ground motion prediction models to assess the potential impact of induced earthquakes	11,000	11,000	11,000	per pad	-	-	-	per pad	Over lifetime of the pad	1,356	1,356	1,356
55d	Microseismicity monitoring and management requirements during operations	-	-	-	per pad	N/A	1,200	-	per pad	Over lifetime of the pad	600	1,200	-
59a	Traffic impact assessment including consideration of noise, emissions and other relevant impacts	15,000	15,000	15,000	per pad	-	-	-	per pad	Over lifetime of the pad	1,849	1,849	1,849
59b	Transport management plan (including consideration of available road, rail, waterway infrastructure)	4,500	4,500	4,500	per pad	-	-	-	per pad	Over lifetime of the pad	555	555	555
CAL1	Require hydraulic fracturing specific chemical safety assessment (through REACH) addressing specific risks associated with unconventional gas and associated pathways for exposure of the environment and humans via the environment (including routes via underground pathways). Appropriate risk management measures to be specified in this assessment.	800	800	800	per pad	-	-	-	per pad	5.00	180	180	180
CAL2	Develop a peer-reviewed EU-level exposure scenario / SpERC for HF for different chemical types.	200	200	200	per pad	-	-	-	per pad	Over lifetime of the pad	25	25	25
CAL3	CAL2 to be implemented in CSAs for chemicals used in HF and any deviations explained	200	200	200	per pad	-	-	-	per pad	5.00	45	45	45
CAM1	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	1,300	1,300	1,300	per pad	-	-	-	per pad	5.00	292	292	292
CSL3	Negative list of named substances that must not be used in UG extraction (alternative to two measures CSL1 and CSL2)	200	200	200	per pad	400	400	400	per pad	5.00	445	445	445
CSM2	Positive list of substances expected to be safe under EU UG extraction conditions and require operators to only use substances on this positive list	200	200	200	per pad	-	-	-	per pad	5.00	45	45	45
N06	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	21,000	21,000	21,000	per pad	2,000	2,000	2,000	per pad	Over lifetime of the pad	4,589	4,589	4,589
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)	80,000	80,000	80,000	per pad	-	-	-	per pad	Over lifetime of the pad	9,863	9,863	9,863

Non-BAU Measures - Quantitative Analysis

Item	Measures	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Amortisation period (years)	Annualised Compliance Cost (€ per pad)		
		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit	MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION
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 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.	77,000	77,000	77,000	per pad	-	-	-	per pad	Over lifetime of the pad	9,493	9,493	9,493
N15	Mandatory EIA for all projects expected to involve hydraulic fracturing, before exploration starts	64,000	64,000	64,000	per pad	-	-	-	per pad	Over lifetime of the pad	7,891	7,891	7,891
N16 i	Mandatory EIA (i) after initial phase of well exploration and before first test fracturing, and (ii) before production commences	64,000	64,000	64,000	per pad	-	-	-	per pad	Over lifetime of the pad	7,891	7,891	7,891
N16 ii	Mandatory EIA (i) after initial phase of well exploration and before first test fracturing, and (ii) before production commences	64,000	64,000	64,000	per pad	-	-	-	per pad	Over lifetime of the pad	7,891	7,891	7,891
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/prospecting and taking account of the entire project)	25,000	25,000	25,000	per pad	-	-	-	per pad	Over lifetime of the pad	3,082	3,082	3,082
N20	Environmental management system accreditation for unconventional gas installation operators	25,000	25,000	25,000	per pad	3,000	3,000	3,000	per pad	Over lifetime of the pad	6,082	6,082	6,082
N27	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	-	-	-	per pad	60	60	60	per pad	Over lifetime of the pad	60	60	60
N30	The European Commission to develop further criteria/guidance for the assessment of environmental impacts from unconventional gas	200	200	200	per pad	-	-	-	per pad	Over lifetime of the pad	25	25	25
N31	Inspections by Competent Authorities during all stages of development (e.g. of well completion reports and environmental risk management and controls)	-	-	-	per pad	10	10	10	per pad	Over lifetime of the pad	10	10	10
N34	Public authorities produce an underground regional impact assessment to optimise resource allocation between unconventional gas and other underground resources (e.g. geothermal energy)	250	250	250	per pad	-	-	-	per pad	Over lifetime of the pad	31	31	31
N40	Member State Competent Authorities provide a map of planned and existing exploration, production and abandoned well locations	-	-	-	per pad	20	20	20	per pad	Over lifetime of the pad	20	20	20
N41	Member State Competent Authorities provide information on the licences and permits of operators involved in unconventional gas exploration and production	-	-	-	per pad	30	30	30	per pad	Over lifetime of the pad	30	30	30

Non-BAU Measures - Quantitative Analysis

Item	Measures	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Amortisation period (years)	Annualised Compliance Cost (€ per pad)		
		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit	MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION	Unit		MIDDLE AMBITION	LOW AMBITION	HIGH AMBITION
N55	Conduct 2D seismic survey to identify faults and fractures	14,000	14,000	14,000	per pad	-	-	-	per pad	Over the lifetime of the pad	1,726	1,726	1,726

Measure summary: 3a Baseline

Ref	Measure description	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
3a i	Baseline - air	5,800	5,800	5,800	per pad	-	-	-	per pad	Over the lifetime of the pad	715	715	715	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). One-off cost including labour and analysis costs of €5800 per pad. Source: AMEC expert judgement based on practical experience of industrial site baseline monitoring in the UK.	Pre-development air quality conditions established against which potential impacts and mitigation measures can be assessed and site closure conditions can be compared.
3a ii	Baseline - surface water	N/A	6,600	28,000	per pad	-	-	-	per pad	Over the lifetime of the pad	2,133	814	3,452	LOW AMBITION Assume one water course baseline establishment per pad. 1 sample per week for 3 months. 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. Analysis cost = €60/sample x 12 weeks (~3 months) = €720. Labour cost = 8 hours x €59/h technical staff x 12 samples = €5664/pad. Equipment €200 once. Total = 720+5664+200= approx. €6600 per pad HIGH AMBITION Assume one water course baseline establishment per pad in both wet and dry periods. 1 sample per week for 12 months. 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. Analysis cost = €60/sample x 52 weeks (12 months) = €3120. Labour cost = 8 hours x €59/h technical staff x 52 samples = €24,544/pad. Equipment €200 once. Total = 3120+24544+200= approx. €28,000 per pad Source: AMEC expert judgement based on practical experience of industrial site baseline monitoring in the UK.	Pre-development surface water conditions in nearby water courses established against which potential impacts and mitigation measures can be assessed and site closure conditions can be compared.
3a iii	Baseline - groundwater	10,000	7,000	1,200,000	per pad	-	-	-	per pad	Over the lifetime of the pad	1,233	863	147,949	LOW AMBITION Concentrate boreholes near pad (as on impacts on groundwater due to e.g. surface spills greatest near pad). Assume 4 x boreholes, at 15m depth at each corner of pad cost €6000 (includes drilling and supervision over 4-5 days). 1 sample per month for 3 months. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons (and also fracturing additive chemicals) and gas. isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals. €60/sample/month x 3 months = €180. Labour: 15 hours at €59/h = €885 for sample collection and analysis of results. Total = 6000+180+885 = approx. 7,000 HIGH AMBITION Sampling of shallow groundwater during wet and dry periods Concentrate boreholes near pad (as on impacts on groundwater due to e.g. surface spills greatest near pad). Assume 4 x boreholes, at 15m depth at each corner of pad cost €6000 (includes drilling and supervision over 4-5 days). 1 sample per month for 12 months. Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons (and also fracturing additive chemicals) and gas isotopic fingerprinting (include methane, ethane, propane), radioactivity and heavy metals. €60/sample/month x 12 months = €720. Labour: 60 hours at €59/h = €3540 for sample collection and analysis of results. Total = 6000+720+3540 = approx. 10,000 VERY HIGH AMBITION Sampling of deeper groundwater at 400m depth (after which sampling borehole not suitable - a well more analogous to a gas well would be needed). Cost estimate including to drill & install, geophysics, permanent pump and consultancy = £250,000 per well. Sampling additional but trivial in comparison to cost of installation. Assume 4 x boreholes = £1m total.` Total = approx. €1,200,000 Source: AMEC expert judgement based on practical experience of industrial site baseline monitoring in the UK and informed by work regarding unconventional gas carried out for the Environment Agency in the UK.	Pre-development groundwater conditions established in the vicinity of the pad against which potential impacts and mitigation measures can be assessed and site closure conditions can be compared.
3a iv	Baseline - drinking water abstraction points	10,000	10,000	10,000	per pad	-	-	-	per pad	Over the lifetime of the pad	1,233	1,233	1,233	Develop list of water wells within area (from public data). US EPA (2010) suggests 36 hours of geologist labour @ $107.23 per hour = $3,860.28 per square mile (or 2.6 square km) in 2008 prices. Once first year. In the European contexts, this would be equivalent to 36h x €59/h = €2124. Assume this cost applies per total 3.2 sq km underground area covered per pad (equiv. 1.2 sq miles). 36 hrs/sq miles x 1.2 sq miles x €59/hr = 2627. List names and depth of all potentially affected underground sources of drinking water: 24 hours of geologist labour @$107.23 per hour = $2,573.52 per site in 2008 prices (US EPA, 2010). Once first year. Equiv: 24h x €59/h = €1416. Provide geochemical information and maps/cross section on subsurface aquifers. 60 hours of geologist labour @$107.23 per hour = $6,433.80 per site in 2008 prices (US EPA, 2010). Once. Equiv: 60h x €59/h = €3540. Obtain water quality data and water gas content from existing available data. Assume desk study search. Labour at €59/h and 40 hours = €2360. Total = 2627+1416+3540+2360 = approx. €10,000	Pre-development drinking water quality established against which potential impacts and mitigation measures can be assessed and site closure conditions can be compared.

Measure summary: 3a Baseline

Ref	Measure description	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
3a v	Baseline - land conditions (soil)	14,000	14,000	14,000	per pad	-	-	-	per pad	Over the lifetime of the pad	1,726	1,726	1,726	€200/sample analysis cost and 3 samples per trial pit (analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, asbestos, chloride). 10-20 trial pits per pad (assume 15). Analysis cost = €200 x 3 samples x 15 pits = €9000. Labour and equipment: €1200/d for 2 days = €2400. Reporting and analysis time €59/h and 40 hours = €2360 per pad. Total = 9000+2400+2360 = approx. €14,000 per pad, once. Source: AMEC expert judgement. (Compares to: develop plan and implement soil zone monitoring. 40 hours of geologist labour @$107.23 per hour = $4,289.20. Total cost = $4,289.20 + $6,000 = $10,289.2 per site in 2008 prices. Once. USEPA 2010.)	Pre-development land (soil) conditions established against which potential impacts and mitigation measures can be assessed and site closure conditions can be compared.
3a vi	Baseline - water resources availability and suitability	51,000	51,000	51,000	per pad	-	-	-	per pad	Over the lifetime of the pad	6,288	6,288	6,288	HIGH. Upper Estimate for the preparation of a consultant study is between $30,000 and $50,000 and includes locating water sources and identifying availability, water rights, and other issues. Additional work to test water sources for suitability (particularly groundwater). Assumed this is cost per pad and assessment is needed once at the start of exploration design and planning. Costs are assumed to be 2012 prices. Source: AMEC expert judgement based on experience of unconventional gas operations in the US. Note costs have been converted in to € based on 2012 average exchange rate. Based on practical experience of shale gas projects in the US (including Marcellus shale and others) transferred to the EU.	Available water resources established which will influence operational factors (for example number of lorry movements) and environmental impact of operation. Likely to influence operational life.
3a vii	Baseline - transport and traffic	N/A	5,000	37,000	per pad	-	-	-	per pad	Over the lifetime of the pad	2,589	616	4,562	<u>Low Ambition</u>: Undertake transport and traffic study. Liaise with highway authority and identify relevant routes to/from well pad and analysis of highway conditions. Estimated at between £3,000 - £5,000. <u>High Ambition</u>: Undertake transport and traffic study. As per LOW plus traffic survey and traffic modelling. A bespoke traffic survey, with traffic counts in a number of locations, is assumed. Costs are typically £10,000 and are based on traffic counts over one week period at c.4 locations. Costs for more complex traffic modelling based on the survey data, are likely to cost up to £30,000. Both estimates are for a typical well pad. Source: AMEC expert judgement based on traffic impact assessments for range of developments in the UK. Costs for the baseline element has been estimated based on the proportion of total work judged to be needed at baseline stage.	Current traffic patterns established, to enable impact assessment of traffic patters/lorry movements associated with development.
3a viii	Baseline - noise	4,600	4,600	4,600	per pad	-	-	-	per pad	Over the lifetime of the pad	567	567	567	There are two methods. Method 1. £5,000 (approx. €6000) based on an assessment for a typical multi well pad. Assumes consulting with relevant regulatory authority and assumes five receptor locations are identified. At each location noise measuring equipment is needed. For a 24 hours period, with consultant visits during the daytime/evening. Source: AMEC expert judgement based on noise assessments for industrial developments in the UK. Method 2. £2,500 (€3000) assuming there would be four receptors at each site, for which noise measuring equipment in place for a 24 hour period would be needed. Cost comprises time for noise testing equipment position, set up, travel time and the equipment itself. Source: AMEC expert judgement based on noise assessments for industrial developments in the UK. Figure assumes the assessment is needed for one typical well pad. An average cost of these two methods have been assumed for the cost of this measure.	Establish existing noise levels, to enable assessment of additional noise arising from construction/operation of well drilling pad, identify receptors and the significance of the change in noise level.
3a ix	Baseline - biodiversity/ecology/invasive species	N/A	41,000	65,000	per pad	-	-	-	per pad	Over the lifetime of the pad	6,534	5,055	8,014	LOW: Assume no protected species, no notable habitats, not a designated site. Perform desk study and extended phase 1 survey (map habitats, walkover survey, assessment). Labour cost €59/h x 70 hours = approx. €4,000 per pad. MEDIUM: Assume some protected species found, some notable habitats, not a designated site. As per LOW plus additional survey time. Labour cost €59/h x 700 hours = approx. €41,000 per pad. HIGH: Assume number of protected species found, notable habitats, and designated site. As per MEDIUM plus additional survey time. Labour cost €59/h x 1100 hours = approx. €65,000 per pad. For this measure, Medium and High estimates have been assumed. Source: AMEC expert judgement based on baseline ecology/biodiversity assessments in the UK for industrial developments including power plants.	Pre-development biodiversity/ecology established against which potential impacts and needed mitigation measures can be assessed and site closure conditions can be compared. Creates baseline against which the presence of evasive species can be evaluated.
3a x-a1	Baseline - geological, hydrogeological and seismic conceptual model: [1] obtain and analyse seismic (earthquake) history	3,500	3,500	3,500	per pad	-	-	-	per pad	Over the lifetime of the pad	432	432	432	Two methods have been considered (3a x-a and 3a x-b). Below is Method 1 (3a x-a), and there are various cost components. Costs are from EPA (2010) referenced in $ in 2008 prices have been converted to € in 2012 prices. [1] Obtain and analyze seismic (earthquake) history. 60 hours of geologist labour @$107.23 per hour = $6,433.80 per site. Once. Equiv: 60h x €59/h = approx. €3500.	Pre-development geological, groundwater flow and microseismicity conditions are established which form the basis of risk management requirements for drilling and fracturing operations. Establishes conditions against which potential impacts and needed mitigation measures can be assessed and site closure conditions can be compared.

Measure summary: 3a Baseline

Ref	Measure description	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
3a x-a2	Baseline - geological, hydrogeological and seismic conceptual model: [2] Obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures	N/A	3,500	290,000	per pad	-	-	-	per pad	Over the lifetime of the pad	18,093	432	35,754	[2] Obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures > LOW AMBITION. This would be based on existing data and literature. 120 hours of geologist labour @$107.23 per hour = $12,867.60 per site. Also needed for well design hence assume 50% of cost is additional to BAU. Equiv. 120h x €59/h = €7080/2 = approx. €3500. > HIGH AMBITION. In addition to existing data and literature, plus obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures (new cores and tests). $78 per foot for stratigraphic test well. $3,100 per core. Once. Also needed for well design hence assume 50% of cost is additional to BAU. Equiv. to sum of 3540 labour cost, €2300 for test and €190/metre x assumed 3,000 metre deep stratigraphic test well x 50% = approx. €290,000.	Pre-development geological, groundwater flow and microseismicity conditions are established which form the basis of risk management requirements for drilling and fracturing operations. Establishes conditions against which potential impacts and needed mitigation measures can be assessed and site closure conditions can be compared.
3a x-a3	Baseline -geological, hydrogeological and seismic conceptual model: [3] Undertake surface microseismic survey	39,000	39,000	39,000	per pad	-	-	-	per pad	Over the lifetime of the pad	4,808	4,808	4,808	[3] Surface microseismic detection equipment: geophone arrays in monitoring wells. $52,000 per geophone array (1 per 5 square miles with a minimum of 1 per site). Once. Equiv. €39000.	Pre-development geological, groundwater flow and microseismicity conditions are established which form the basis of risk management requirements for drilling and fracturing operations. Establishes conditions against which potential impacts and needed mitigation measures can be assessed and site closure conditions can be compared.
3a x-a4	Baseline - geological, hydrogeological and seismic conceptual model: [4] Complex modelling of fluid flows and migration (reservoir simulations)	N/A	33,000	43,000	per pad	N/A	2,700	3,500	per pad	Over the lifetime of the pad	7,785	6,769	8,802	[4] Complex modelling of fluid flows and migration (reservoir simulations) > LOW AMBITION. Modelling is done over 100 years: 70 hours of engineer labour @$110.62 per hour = $7,743.40 per well for 100 years. Once (and then every five years). Equiv. 70h x €59/h = €4130 per well. 8 wells per pad, therefore approx. €33000 per pad. Assumed to occur every five years over 10 years. > HIGH AMBITION. Modelling is done over 10,000 years: 90 hours of engineer labour @$110.62 per hour = $9,955.80 per well for 10,000 years. Once (and then every five years). Equiv. 90h x €59/h = €5310 per well. 8 wells per pad, therefore approx. €43000 per pad. Assumed to occur every five years over 10 years.	Pre-development geological, groundwater flow and microseismicity conditions are established which form the basis of risk management requirements for drilling and fracturing operations. Establishes conditions against which potential impacts and needed mitigation measures can be assessed and site closure conditions can be compared.
3a x-a5	Baseline - geological, hydrogeological and seismic conceptual model: [5] Develop maps and cross sections of local geologic structure	3,500	3,500	3,500	per pad	-	-	-	per pad	Over the lifetime of the pad	432	432	432	[5] Develop maps and cross sections of local geologic structure. 60 hours of geologist labour @$107.23 per hour = $6,433.80 per site. Once. USEPA 2010. Once. Equiv: 60h x €59/h = approx. €3500.	Pre-development geological, groundwater flow and microseismicity conditions are established which form the basis of risk management requirements for drilling and fracturing operations. Establishes conditions against which potential impacts and needed mitigation measures can be assessed and site closure conditions can be compared.
3a x-a6	Baseline - geological, hydrogeological and seismic conceptual model: [6] Conduct 3D seismic survey to identify faults and fractures	N/A	-	360,000	per pad	-	-	-	per pad	Over the lifetime of the pad	22,192	-	44,385	[6] Conduct 3D seismic survey to identify faults and fractures. LOW AMBITION: This activity is not considered in the low ambition scenario. HIGH AMBITION: $104,000 per square mile of AOR (plus a mile past the perimeter) for good resolution. Once. USEPA 2010. Assumed an underground area of 3.2 square kilometres, which is equivalent to 1.2 square miles. Adding a mile past the perimeter would lead the area for the survey to be 4.5 square miles. $104,000 x 4.5 sq. miles = $464,000, which is equiv. to approx. €360,000.	Pre-development geological, groundwater flow and microseismicity conditions are established which form the basis of risk management requirements for drilling and fracturing operations. Establishes conditions against which potential impacts and needed mitigation measures can be assessed and site closure conditions can be compared.
3a x-a7	Baseline - geological, hydrogeological and seismic conceptual model: [7] Obtain data on area, thickness, capacity, porosity and permeability of formations	1,400	1,400	1,400	per pad	-	-	-	per pad	Over the lifetime of the pad	173	173	173	[7] Obtain data on area, thickness, capacity, porosity and permeability of formations. 24 hours of geologist labour @$107.23 per hour = $2,573.52 per site. Once. USEPA 2010. Once. Equiv: 24h x €59/h = approx. €1400.	Pre-development geological, groundwater flow and microseismicity conditions are established which form the basis of risk management requirements for drilling and fracturing operations. Establishes conditions against which potential impacts and needed mitigation measures can be assessed and site closure conditions can be compared.
3a xi	Baseline - presence of methane seepages in groundwater, including drinking water.	-	-	-	per pad	-	-	-	per pad	Over the lifetime of the pad	-	-	-	Cost included in 3a iii & iv	Pre-development underground gas seepages established against which potential impacts and needed mitigation measures can be assessed and site closure conditions can be compared.
3a xii	Baseline - existing land use, infrastructure, buildings	N/A	1,800	4,300	per pad	-	-	-	per pad	Over the lifetime of the pad	376	222	530	LOW AMBITION. Desk study and mapping of land use, infrastructure and buildings. Assume 30 h @ €59/h = approx. €1800. Source: AMEC expert judgement. HIGH AMBITION. As above plus remote (aerial) survey of land, land uses, structures etc. $3,100 per site. $415 per square mile (2.6 sq km) surveyed. Once. USEPA 2010. Assuming 2.24 hectare area, Equiv: €2560 (2012). Total = 1770+2560 = approx. €4300.	Pre-development land use, infrastructure and buildings established. Potential impacts and needed mitigation measures can be assessed.
3a xiii	Baseline - existing underground wells and structures	N/A	900	3,200	per pad	-	-	-	per pad	Over the lifetime of the pad	253	111	395	LOW AMBITION. Develop list of penetrations into zone within area (from well history databases). 12 hours of geologist labour @ 107.23 per hour = $1,286.76 per square mile. Once. USEPA 2010. Equiv: 12h x €59/h = €708. Assessment for 3.2 sq km = 1.2 sq miles, hence 1.2 x €708 = approx. €900. HIGH AMBITION. As above plus: desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells (e.g. for water abstraction). Assume 40 hours @ €59/h = €2360. Total = 850+2360 = approx. €3,200.	Pre-development condition of underground wells and structures established. Potential impacts and needed mitigation measures can be assessed.

Measure summary: 3b Monitoring and reporting

Ref	Measure description	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
3b i	M&R - air	-	-	-	per pad	5,800	5,800	5,800	per pad	N/A	5,800	5,800	5,800	On-going monitoring 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). On-going cost including labour and analysis costs of €5800 per pad per annum. Source: AMEC expert judgement based on practical experience of industrial site baseline monitoring in the UK.	Actual impacts on air quality and the performance of mitigation measures can be verified and reported.
3b ii	M&R - surface water	N/A	-	5,000	per pad	2,000	2,000	2,000	per pad	N/A	2,308	2,000	2,616	LOW AMBITION Assume one water course would need ongoing monitoring per pad (wet and dry periods). 1 sample each quarter = 4 samples per annum. 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. Analysis cost = €60/sample x 4 months = €240. Labour cost = 8 hours x €59/h technical staff x 4 = €1888/pad/a. HIGH AMBITION As LOW AMBITION with alert system prompting corrective action for relevant parameters identified on a site risk basis. Allowance for capital cots of €5,000 made for alert system. LOW: Total = 240+1888 = approx. €2000. HIGH: Total = €2000 (annual) and €5,000 (capital) Source: AMEC expert judgement based on practical experience of industrial site baseline monitoring in the UK.	Actual impacts on surface water bodies and the performance of mitigation measures can be verified and reported.
3b iii	M&R - groundwater	N/A	11,000	-	per pad	N/A	-	11,000	per pad	N/A	6,178	1,356	11,000	Assume use of boreholes near pad established for baseline monitoring hence no additional cost (comprises 4 x boreholes, at 15m depth at each corner of pad cost. LOW AMBITION. Assume monthly sampling during wet and dry periods during drilling and fracturing operations only. 1 sample per month. 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. €60/sample x 12 = €720. Labour time 15 hours at €59/h x 12 = €10620 for sample collection and analysis of results. LOW AMBITION. Total = 720+10620 = approx. €11000 one year after drilling and fracturing operations have been completed. HIGH AMBITION. Assumed use of deep boreholes near pad established for measure 3a iii Groundwater Baseline Monitoring in VERY HIGH AMBITION option (£1m, approx. €1.2m). €60/sample x 12 = €720. Labour time 15 hours at €59/h x 12 = €10620 for sample collection and analysis of results. 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. HIGH AMBITION. Total = approx. €11000 per year during lifetime of a well pad NB alert system not relevant to groundwater due to slow movement of pollutant. Pollutant would have been released some time before reaching monitoring point. Source: AMEC expert judgement based on practical experience of industrial site baseline monitoring in the UK and informed by work regarding unconventional gas carried out for the Environment Agency in the UK.	Actual impacts on groundwater in the vicinity and the pad and the performance of mitigation measures can be verified and reported.
3b iv	M&R - drinking water abstraction points	-	-	-	per pad	2,400	2,400	2,400	per pad	N/A	2,400	2,400	2,400	Obtain water quality data and water gas content from existing available data. Assume annual desk study. Labour at €59/h and 40 hours = approx. €2400. Source: AMEC expert judgement based on assumptions for technical desk study.	Any impacts on drinking water can be evaluated and reported.
3b v	M&R - land conditions (soil)	-	-	-	per pad	400	400	400	per pad	N/A	400	400	400	Soil zone monitoring. $200 lab fee + $100 to collect per sample = $300 per sample. Annual. USEPA 2010. Assume for analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, chloride) every five years and 20 samples taken from outside site boundary around the site. Equiv to €222 per sample (2012). Assuming 20 samples per monitoring test occurring every 5 years for 10 years assumed for a well lifetime. Source: AMEC expert judgement based on experience of carrying out baseline and site investigation surveys of industrial site and contaminated land.	Any impacts on land conditions (soil) can be evaluated and reported.
3b vi	M&R - water resources availability	-	-	-	per pad	2,400	2,400	2,400	per pad	N/A	2,400	2,400	2,400	Assume labour cost for management and continual assessment of water resource availability of 40 hours per year @ €59/hour = approx. €2400 per year during fracturing. Source: AMEC expert judgement based on assumptions for technical desk study.	The availability and impacts on water resources can be evaluated and reported.

Measure summary: 3b Monitoring and reporting

Ref	Measure description	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
3b vii	M&R - traffic	-	-	-	per pad	3,100	3,100	3,100	per pad	N/A	3,100	3,100	3,100	A permanent traffic count site/system can provide weekly or monthly counts. Prices quote (2011) from a UK based provider are: £2,625 to install (equiv. €3100). Assume 0.5 days of consultant times to analyse the data per instance. Annual maintenance cost is £250 (2011 prices). Annualised installation cost over the lifetime of a well (10 years; 4% discount rate) is €300 in 2012 prices. Assuming monthly analysis of data and annual maintenance costs, operating cost equals to (0.5d x 12 x 7.5h/d x €59/h) + €300 = €2950 in 2012 prices. Combined, the annual cost is approx. €3300. Alternatively, £7,250 which includes installation and data retrieval and reporting for three years. Spread over 3 years, this is equivalent to approx. €2900 per year. Thus the cost is estimated to be €2900 to €3300, with an average cost of €3100. Source: AMEC expert judgement based on experience of traffic monitoring programmes for a variety of projects and developments in the UK.	Understanding of actual lorry movement compared to expectations, demonstrate compliance with potential permits/restrictions on traffic volumes and hours of operation. Improves ability of future operators and authorities to understand impact of development and costs/logistics of operation.
3b viii	M&R - noise	-	-	-	per pad	11,000	11,000	11,000	per pad	N/A	11,000	11,000	11,000	Method 1. £10,000 per well pad, involves predictions of likely noise levels, based on specifications of plant/equipment. Ongoing monitoring will depend on the nature of the well drilling operation, although such monitoring may not be necessary (i.e. if the well is sealed). Assumes that detailed noise prediction modelling is not needed and is based on an assessment that would be needed for a typical multi well pad. Approx. €12,000 per year. Source: AMEC expert judgement based on noise assessments for industrial developments in the UK. Method 2. £8-9,000 per well pad. This comprises £3,000 for noise monitoring (this is assumed to be over a 24 hour period, as at baseline). A fuller analysis of noise at operational as well as construction stage which includes impact assessment, costs around £5,000 to £6,000 in addition to the monitoring requirements. Approx. €10,000 per year. An average cost of €11,000 has been assumed for the measure. Source: AMEC expert judgement based on noise assessments for industrial developments in the UK.	Actual impacts on noise levels and the performance of mitigation measures can be verified and reported.
3b ix	M&R water volumes and origin	-	-	-	per pad	2,000	2,000	2,000	per pad	N/A	2,000	2,000	2,000	Assume labour cost for recording and reporting water volumes and origin of 50 hours per year @ €39/hour (operator) = approx. €2000. Source: AMEC expert judgement based on experience of industrial environmental management at industrial sites in the UK.	Chemicals and proppant volumes and efficiency of use can be monitored and reported.
3b x	M&R - chemicals nature and volume used (i.e. record keeping)	-	-	-	per pad	2,000	2,000	2,000	per pad	N/A	2,000	2,000	2,000	Assume labour cost for recording and reporting (e.g. disclosure to public website and authorities) of 50 hours per year @ €39/hour (operator) = approx. €2000. Source: AMEC expert judgement based on experience of industrial environmental management at industrial sites in the UK.	Water volumes and efficiency of water using processes (fracturing) can be monitored and reported.
3b xi	M&R - energy source and use	-	-	-	per pad	2,000	2,000	2,000	per pad	N/A	2,000	2,000	2,000	Assume labour cost for recording and reporting of 50 hours per year @ €39/hour (operator) = approx. €2000. Source: AMEC expert judgement based on experience of industrial environmental management at industrial sites in the UK.	Energy source (e.g. diesel, LPG, grid electricity) can be monitored and reported.
3b xii	M&R - greenhouse gas emissions	-	-	-	per pad	2,000	2,000	2,000	per pad	N/A	2,000	2,000	2,000	Assume labour cost for analysis of fuel consumption, calculation of GHG emissions and reporting of 50 hours per year @ €39/hour (operator) = approx. €2000. Source: AMEC expert judgement based on experience of industrial environmental management at industrial sites in the UK.	GHG emissions can be monitored and reported.
3b xiii	M&R - drilling mud volumes and treatment	19,000	19,000	19,000	per pad	-	-	-	per pad	Over the lifetime of the pad	2,343	2,343	2,343	Assume two mud/cutting samples during the course of drilling or once drilling is complete. Analyse for VOCs, metals, total petroleum hydrocarbons, NORM at €400/sample. Reporting and analysis assume 40 hours @ €39/h (operator) = €1560. Total = 800+1560 = approx. €2400 per well. With 8 wells per pad, the cost is approx. €19,000 per pad. Source: AMEC expert judgement based on practical experience of shale gas projects in the US (including Marcellus shale and others) transferred to the EU.	Mud volumes and efficiency of use can be monitored and reported.
3b xiv	M&R - flowback water return rate	89,000	89,000	89,000	per pad	-	-	-	per pad	Over the lifetime of the pad	10,973	10,973	10,973	Assume weekly sampling for a 2 month fracturing operation. Analyse for oil & grease, BTEX, VOCs, SVOCs, TDS, pH, sulphates, H2S, heavy metals, NORM, biocides, emulsion breakers, corrosion inhibitors. Assume €800/sample x 8 = €6400 per fracturing operation. Reporting and analysis assume 120 hours @ €39/h (operator) = €4680 per fracturing operation. Total = 6400+4680 = approx. €11,000 per well per fracturing operation. With 8 wells per pad, the cost is €89,000 per pad. Source: AMEC expert judgement based on practical experience of shale gas projects in the US (including Marcellus shale and others) transferred to the EU.	Flowback return and potential for recycling can be monitored and reported.
3b xv	M&R - produced water volume and treatment solution	-	-	-	per pad	47,000	47,000	47,000	per pad	N/A	47,000	47,000	47,000	Assume weekly sampling. Analyse for oil & grease, BTEX, VOCs, SVOCs, TDS, pH, sulphates, H2S, heavy metals, NORM, biocides, emulsion breakers, corrosion inhibitors. Assume €800/sample x 52 per year = €41600 per year. Reporting and analysis assume 150 hours per year @ €39/h (operator) = €5850 per year. Total = 41600+5850 = approx. €47,000 per well per year in production Source: AMEC expert judgement based on practical experience of shale gas projects in the US (including Marcellus shale and others) transferred to the EU.	Produced water volume can be monitored and reported.

Measure summary: 3b Monitoring and reporting

Ref	Measure description	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
3b xvi	M&R - biodiversity/ecology/invasive species	-	-	-	per pad	800	300	1,400	per pad	Variable	850	300	1,400	LOW: Assume no protected species, no notable habitats, not a designated site. Assume repeat survey every 5 years in pad vicinity (desk study and extended phase 1 survey to map habitats, walkover survey, assessment) to monitor for invasive species. Labour cost €59/h x 70 hours = €4130 per pad every 5 years. In annualised terms, this is €300 per year. MEDIUM: Assume some protected species found, some notable habitats, not a designated site. Assume repeat survey every 5 years in pad vicinity. Labour cost €59/h x 160 hours = €9450 per pad every five years. In annualised terms, this is approx. €800 per year. HIGH: Assume number of protected species found, notable habitats, and designated site. Assume repeat survey every 5 years in pad vicinity. Labour cost €59/h x 280 hours = €16540 per pad per every three years. In annualised terms, this is €1400 per year. For detailed calculations, please see below. Implement invasive species mitigation plan if needed. Source: AMEC expert judgement based on baseline ecology/biodiversity assessments in the UK for industrial developments including power plants.	Impacts on biodiversity/ecology can be monitored and reported. The performance of mitigation measures can be verified and reported. The introduction of invasive species can be evaluated and necessary mitigation measures put in place to control invasive species.
3b xvii	M&R - induced seismicity from fracturing	-	-	-	per pad	12,000	12,000	12,000	per pad	N/A	12,000	12,000	12,000	Annual cost of passive seismic equipment. $10,500 per geophone array. Annual. USEPA 2010. Equiv. €7788 (2012). Assume labour cost for recording 100 hours per year @ €39/hour (operator) = €3900. Total = 7788+3900 = approx. €12,000 per site per year.	Induced seismicity can be monitored and reported. The performance of mitigation measures (e.g. management control) can be verified and reported.
3b xviii	M&R - presence of methane seepages in groundwater, including drinking water.	-	-	-	per pad	-	-	-	per pad	N/A	-	-	-	Cost included in 3b iii & iv	The presence of methane and the performance of mitigation measures can be verified and reported.
3b xix	M&R - spills volume, nature, location and clean-up (includes reporting)	-	-	-	per pad	2,000	2,000	2,000	per pad	N/A	2,000	2,000	2,000	Assume labour cost for recording and reporting of 50 hours per year @ €39/hour (operator) = approx. €2,000 per year Source: AMEC expert judgement based on experience of industrial environmental management at industrial sites in the UK.	The nature or and impact of spills can be recorded to enable practice to be improved and needed mitigation and/or clean up measures to be put in place.

Measure summary: 12 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)

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
12	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)	413,000	413,000	413,000	per pad	-	-	-	per pad	Over the lifetime of the pad	50,919	50,919	50,919	Flush wells with a buffer fluid before plugging. $1,000 per injection well + $0.085 per foot depth. Once. USEPA 2010. Assume 3000m (9842 feet) well. Equiv. €1360 per well, once (2012). 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. $13,500 to plug and $11,400 to log. Once. USEPA 2010. Equiv to €18470 per well, once (2012). Perform a mechanical integrity test prior to plugging to evaluate integrity of casing and cement to remain in ground. $2,070 per well plus $4.15 per foot depth. Once USEPA. Assume 3000m (9842 feet) well. Equiv. €31830 per well, once (2012). Total (one-off) = 1360+18470+31830 = approx. €52000 per well. Assuming 8 wells, total cost per pad equals to €413,000 per pad Exclude the following operating cost as 'temporary closure' assumed to be months rather than years: External mechanical integrity tests to detect flow adjacent to well using temperature or noise log at least annually. $2,070 per test (one test per well) plus $4.15 per foot depth. Annual. USEPA 2010. Assume 3000m (9842 feet) well. Equiv. €31830 per well per year (2012).	Applies to temporarily closed wells. Assurance that wells closed for short periods do not pose unacceptable risks to health or the environment. Assurance that wells are the necessary plugs in place to prevent migration of potentially polluting substances to, e.g. aquifers and that well integrity continues to be evaluated to ensure the well remains fit for purpose.

Measure summary: 13d Abandonment survey

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
13d i	Abandonment - air	-	-	-		-	-	-		Not Needed	-	-	-	Not Needed	Not Needed
13d ii	Abandonment - surface water	13,000	13,000	13,000	per pad	-	-	-	per pad	Over the lifetime of the pad	1,603	1,603	1,603	Assume one water course requires baseline establishment per pad. 1 sample per week for 3 months. 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. Analysis cost = €60/sample x 22 weeks (~3 months) = €1320. Labour cost = 8 hours x €59/h technical staff x 22 = €10384/pad. Assessment and reporting against baseline = 24 hours labour @ €59/h = €1416/pad Total = 1320+10384+1416= approx. €13,000 per pad Source: AMEC expert judgement based on practical experience of industrial site baseline monitoring in the UK.	Assurance that on abandonment, surface water quality is comparable to the baseline conditions established pre-development.
13d iii	Abandonment - groundwater	N/A	7,500	8,100	per pad	-	-	-	per pad	Over the lifetime of the pad	962	925	999	Assume use 4 x existing boreholes (at 15m depth at each corner of pad). 1 sample per month for 3 months. 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. €60/sample x 3 months = €180. Labour time 15 hours at €59/h = €885 for sample collection and analysis of results. Monitoring borehole closure cost, assume €5000/pad. Assessment and reporting against baseline = 24 hours labour @ €59/h = €1416/pad. **LOW AMBITION** Total = 180+885+5000+1416 = approx. €7500 HIGH AMBITION. Assumed use of boreholes near pad established for measure 3a iii Groundwater Baseline Monitoring in VERY HIGH AMBITION option (£1m, approx. €1.23m). Assume cost per sample is €60/sample and £500 (equiv. to €616) to collect. With 12 samples per year, this amounts to (€60 + €616) x 12 = €8116 (approx. 8100). Analyse for dissolved oxygen, pH, ammonia, chloride, total petroleum hydrocarbons and polyaromatic hydrocarbons, fracturing additive chemicals if possible, isotopic fingerprinting (include methane, ethane, propane) and heavy metals. **HIGH AMBITION**. Total = €8100	Assurance that on abandonment, groundwater quality is comparable to the baseline conditions established pre-development.
13d iv	Abandonment - drinking water abstraction points	6,500	6,500	6,500	per pad	-	-	-	per pad	Over the lifetime of the pad	801	801	801	[1] Check existing baseline list of water wells within area (from public data). Assume 50% of the following (baseline) cost: 36 hours of geologist labour @ 107.23 per hour = $3,860.28 per square mile (or 2.6 square km). Once. USEPA 2010. Equiv: 36h x €59/h = €2124, 50% = €1062. Assume this cost applies per total 24 sq km area covered per pad. [2] Check existing baseline names and depth of all potentially affected underground sources of drinking water. Assume 50% of the following (baseline) cost: 24 hours of geologist labour @$107.23 per hour = $2,573.52 per site. Once first year. (USEPA 2010). Equiv: 24h x €59/h = €1416, 50% = €708. [3] Obtain water quality data and water gas content from existing available data. Assume desk study search. Labour at €59/h and 40 hours = €2360. [4] Assessment and reporting against baseline = 40 hours labour @ €59/h = €2360/pad Total = 1062+708+2360+2360 = approx. €6500	Assurance that on abandonment, drinking water quality is comparable to the baseline conditions established pre-development.
13d v	Abandonment - land conditions (soil)	16,000	16,000	16,000	per pad	-	-	-	per pad	Over the lifetime of the pad	1,973	1,973	1,973	€200/sample analysis cost and 3 samples per trial pit (analyse for total petroleum hydrocarbons, polyaromatic hydrocarbon, metals suite, pH, sulphate, asbestos, chloride). 10-20 trial pits per pad (assume 15). Analysis cost = €200 x 3 samples x 15 pits = €9000. Labour and equipment: €1200/d for 2 days = €2400. Reporting and analysis time €59/h and 40 hours = €2360 per pad. Assessment and reporting against baseline = 40 hours labour @ €59/h = €2360/pad Total = 9000+2400+2360+2360 = approx. €16000 per pad . Source: AMEC expert judgement based on experience of carrying out baseline and site investigation surveys of industrial site and contaminated land.	Assurance that on abandonment, no land contamination has taken place and conditions are comparable to the baseline conditions established pre-development.
13d vi	Abandonment - biodiversity/ecology/invasive species	48,000	6,000	74,000	per pad	-	-	-	per pad	Over the lifetime of the pad	4,932	740	9,124	LOW: Assume no protected species, no notable habitats, not a designated site. Perform desk study and extended phase 1 survey (map habitats, walkover survey, assessment). Labour cost €59/h x 70 hours = €4130 per pad plus assessment and reporting against baseline = 30 hours labour @ €59/h = €1770/pad. Total = 4130+1770 = approx. €6000 per pad. MEDIUM: Assume some protected species found, some notable habitats, not a designated site. As per LOW plus additional survey time. Labour cost €59/h x 700 hours = €41300 per pad plus assessment and reporting against baseline = 40 hours labour @ €59/h = €2360/pad. Total = 4130+41300+2360 = approx. €48000 per pad. HIGH: Assume number of protected species found, notable habitats, and designated site. As per MEDIUM plus additional survey time. Labour cost €59/h x 1100 hours = €64900 per pad plus assessment and reporting against baseline = 80 hours labour @ €59/h = €4720/pad. Total = 4130+64900+4720 = approx. €74000 per pad. Source: AMEC expert judgement based on baseline ecology/biodiversity assessments in the UK for industrial developments including power plants.	Assurance that on abandonment, there has been no adverse impact on biodiversity and invasive species have been controlled/removed.
13d vii	Abandonment - presence of methane seepages	-	-	-		-	-	-		N/A	-	-	-	Cost included in 13b iii & iv	Assurance that on abandonment, methane seepages (if any) are comparable to the baseline conditions established pre-development.

Measure summary: 13d Abandonment survey

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
13d viii	Abandonment - existing landuse, infrastructure, buildings	N/A	3,500	6,300	per pad	-	-	-	per pad	Over the lifetime of the pad	604	432	777	LOW AMBITION. Desk study and mapping of land use, infrastructure and buildings. Assume 30 h @ €59/h = €1770 plus assessment and reporting against baseline = 30 hours labour @ €59/h = €1770/pad. Total = 1770+1770 = approx. €3500 per pad. Source: AMEC expert judgement. HIGH AMBITION. As above plus remote (aerial) survey of land, land uses, structures etc. $3,100 per site. $415 per square mile (2.6 sq km) surveyed. Once. USEPA 2010. Assuming 2.24 sq km area, Equiv: €380 (2012). Plus assessment and reporting against baseline = 40 hours labour @ €59/h = €2360/pad. Total = 3540+380+2360 = approx. €6,300 per pad.	Assurance that on abandonment, any changes to land use, infrastructure and buildings compared to the baseline are documented.
13d ix	Abandonment - undertake assessment of ex-anti underground wells and structures	N/A	2,200	5,200	per pad	-	-	-	per pad	Over the lifetime of the pad	456	271	641	LOW AMBITION. Check baseline list of penetrations into zone within area (from well history databases). Assume 50% of the following (baseline) cost: 12 hours of geologist labour @ 107.23 per hour = $1,286.76 per square mile. Once. USEPA 2010. Equiv. 12h x €59/h = €708. Require assessment for 3.2 sq km = 1.2 sq miles, hence 1.2 x €708 = €876, assume 50% as repeat of baseline = €438. Plus assessment and reporting against baseline = 30 hours labour @ €59/h = €1770/pad. Total = 438+1770 = approx. €2,200 per pad. HIGH AMBITION. As above plus: desk study to evaluate integrity of construction and record of completion and/or plugging of existing shallow wells (e.g. for water abstraction). Assume 40 hours @ €59/h = €2360 and assume 50% as repeat of baseline = €1180. Plus assessment and reporting against baseline = 30 hours labour @ €59/h = €1770/pad. Total = 2210+1180+1770 = approx. €5200 per pad. Relates to wells and structures in place prior to UG activities.	Assurance that on abandonment, existing underground wells and structures are comparable to the baseline conditions established pre-development.

Measure summary: 15i Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) permitting

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
15i	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) permitting	N/A	11,000	32,000	per pad	N/A	-	2,000	per pad	Over the lifetime of the pad	3,651	1,356	5,945	This is for Suboption 15 ii. LOW AMBITION. Permitting (e.g. website, information, public meetings). Assume one off cost of 160 hours @ €39/h (operator) = €6240 per pad. Abandonment and relinquishing of permits. (e.g. website and information). Assume one off cost of 120 hours @ €39/h (operator) = €4680 per pad. Total = 6240+4680 = approx. €11000 one off costs per pad. HIGH AMBITION. As per low ambition PLUS the following: Early stage consultation (initial exploration, pre-site development and pre-permitting) consultation at (e.g. website, information preparation, public meetings). Assume one off cost of 350 hours @ €59/h = €20650 per pad. Production stage ongoing consultation (e.g. ongoing website and information provision). Assume annual cost of 200 hours @ €59/h = €11800 per year for a 5 pad cluster = €2360 per pad per annum. Total = 10920+20650 = approx. €32000 one off cost per pad PLUS €2000 per pad per annum Source: AMEC expert judgement based on experience of public engagement required from regulatory permits and also from designing and managing stakeholder engagement exercises on contentious developments and schemes in the UK.	Assurance that stakeholders are properly informed with relevant information at the correct time throughout the lifetime of the site to ensure reasonable scrutiny of operator performance and to enhance operator performance where possible.

Measure summary: 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

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
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	31,000	31,000	31,000	per pad	-	-	-	per pad	Over the lifetime of the pad	3,822	3,822	3,822	One-off costs based on consultation with AMEC AQ experts assuming consultants would be used (assuming 50% of sites would require more detailed AQ modelling to look at potential impacts on nearby population and/or sensitive habitats). Amortisation period assumed to be lifetime of pad.	Plan will identify options for emissions reduction - benefits of these will be included against specific measures.

Measure summary: 16b i Low emission power supply (i) LPG or (ii) grid electricity rather than diesel

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
16b i	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	-	-	-	per pad	48,000	48,000	48,000	per pad	5	48,000	48,000	48,000	Assumed zero capital cost as services contracted in i.e. operator could choose supplier with engines running on LPG. In absence of how costs may differ relative to a supplier using diesel engines, we have calculated differences in running costs (fuel) and assumed that any differences would be reflected in the costs incurred by the operator. Fuel prices for diesel and LPG based on www.energy.eu and are net of taxes and duties. It should be noted that if this measure is mutually exclusive to measure 16b ii, 16d and 29c.	Reduced emissions of NOx and PM.
16b ii	Low emission power supply (i) LPG or (ii) grid electricity rather than diesel	250,000	250,000	250,000	per pad	216,000	216,000	216,000	per pad	5	272,157	272,157	272,157	Capital cost based on AMEC internal expert knowledge of grid connection costs (transmission and distribution expert), assuming 1km length, 3-core 120mm cable. Calculated differences in running costs (fuel/electricity) and assumed that any differences would be reflected in the costs incurred by the operator. Assumes that infrastructure for connection to grid is readily available. If not then costs are underestimated. It should be noted that if this measure is mutually exclusive to measure 16b ii, 16d and 29c.	Zero emissions at source so reduced exposure for workers and local population. Will lead to increase in emissions at power stations (unless sourced from renewables).

Measure summary: 16d Application of abatement techniques to minimise emissions (assumed SCR for NOx and Diesel Particulate Filter (DPF) for PM).

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
16d	Application of abatement techniques to minimise emissions (assumed SCR for NOx and Diesel Particulate Filter (DPF) for PM).	229,000	229,000	229,000	per pad	5,700	5,700	5,700	per pad		30,398	30,398	30,398	Based on average engine size for drilling rig and well injection of around 300kW and approximately 8 engines per rig / 8 engines for well injection. It is assumed that 16 engines (used to drill one well) are used at any one time. Costs have been estimated by dividing total costs for DPFs and SCR according to the number of wells/pads that could be drilled over an 8 year lifetime (assuming 52 days drilling per well (see illustrative play) and a lifetime utilisation rate of 50%). Whilst operators are likely to contract this equipment in, it is reasonable to assume that a contractor who has retrofitted their engines and incurred these costs would want to pass them through to the operator (assume annualised costs would represent cost increase for operators).	Assumed abatement efficiency of 95% of PM emissions. Assumed abatement efficiency of 85% of NOx emissions
	PM - DPF	70,000	70,000	70,000	per pad	2,800	2,800	2,800	per pad	8	13,197	13,197	13,197		Assumed abatement efficiency of 95% of PM emissions
	NOx - SCR	159,000	159,000	159,000	per pad	2,900	2,900	2,900	per pad	15	17,201	17,201	17,201		Assumed abatement efficiency of 85% of NOx emissions

Measure summary: 17b Reduced emission completions to eliminate gas venting: prohibit venting of gas; capture and cleaning for use of gas released from fracture fluid and produced water

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
17b	Reduced emission completions to eliminate gas venting: prohibit venting of gas; capture and cleaning for use of gas released from fracture fluid and produced water	176,000	176,000	176,000	per pad	- 50,000	- 50,000	- 50,000	per pad	Over the lifetime of the pad	- 28,301	- 28,301	- 28,301	Costs per REC event (i.e. per well) are based on incremental REC contracted service rather than purchase of equipment (data is available on this as well). Negative as they include the savings based on gas and condensate recovered per REC event. Cost per pad has been estimated using the illustrative play assumption of 8 wells per pad.	Reduced emissions to air and/or flaring. EPA 2011 estimates the following emission reductions per event: - methane: 129 tonnes - VOCs: 19 tonnes - Hazardous air pollutants: 1.4 tonnes (these are defined as organic HAP such as hexane and BTEX compounds (benzene, toluene, ethylbenzene and xylenes))

Measure summary: 17c Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network)

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
17c	Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network)	N/A	21,000	21,000	per pad	-	-	-	per pad	Over the lifetime of the pad	2,589	2,589	2,589	LOW AMBITION: EPA 2011 conservatively assumes one device will control one completion per year. Assumed one completion is for per well, and cost is estimated per pad, assuming 8 wells per pad. HIGH AMBITION - In addition to Low Ambition, no visible or audible flaring is to be added. No data has been located for this additional function, so the cost is assumed to be the same as Low Ambition.	Reduced methane and VOC emissions to air. However, use of flares will lead to emissions to air of products of combustion (nitrogen oxides (NOx), carbon monoxide (CO), sulphur oxides (SOx), carbon dioxide (CO2), and smoke / particulates (PM)).

Measure summary: 22a Key elements to maintain well safety

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
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	7,000,000	7,000,000	7,000,000	per pad	-	-	-	per pad	Over the lifetime of pad	863,037	863,037	863,037	These are standard industry practice design, but are not specific requirements under existing regulation. An indication of a 10% cost increment to drilling and cementing service costs to account for such measures is in IEA Golden Rules (pp55). Assumed a typical well cost to completion is $8 million in the US and in Europe the cost is 30 to 50% more expensive (IEA), making the well cost to completion to be $11.2 million, equiv. to €8.7 million in 2012 prices. 10% of this cost is €870,000 per well. With 8 wells per pad, the cost is approximately €7 million per pad.	
22a ii	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)	See qualitative assessment				See qualitative assessment								To be described qualitatively as dependent on location, depth, aquifers etc.	
22a iii	casings: surface casing cemented before reaching a certain depth (e.g. 75m below as discussed in AEA 2012 report) underground drinking water	See qualitative assessment				See qualitative assessment								To be described qualitatively as dependent on location, depth, aquifers etc.	
22a iv	casings: production casing cemented up to a certain distance (e.g. at least 150 metres as discussed in AEA 2012 report) above the formation where hydraulic fracturing will be carried out	See qualitative assessment				See qualitative assessment								To be described qualitatively as dependent on location, depth, aquifers etc.	

Measure summary: 22b Integrity testing at key stages in well development

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
22b i	Integrity testing at key stages in well development e.g. before/during/after all HF - wire line logging (calliper, cement bond, variable density)	25,000	25,000	25,000	per pad	2,000	2,000	2,000	per pad	Over the lifetime of the pad	5,082	5,082	5,082	Wireline logging is a geophysical tool to test various parameters related to well integrity. It is typically run several times per well. A simple wireline logging test as a part of hydro-geological baseline test for a 100m well for 2-3 hours (running the log) would be about £500 per test. The costs would be higher for a more complicated test and if the test would happen once the well is in operation (as the well is not empty and makes it complicated to run a wireline logging tests). Assumed 5 wireline testing per well. Total is approx. €3000 per well in 2012 prices, and €25,000 per pad. Annualised cost of wireline logging (every five years) is €2000 per pad (2012 prices). Source: AMEC expert judgement based on experience of research and development of well design guidelines for unconventional gas the Environment Agency, England.	Testing integrity of wells would likely to reduce the risks of allowing the wells to develop potential leaks, therefore reduced likelihood of potential leakage of pollutants from wells
22b ii	Integrity testing at key stages in well development e.g. before/during/after all HF - pressure (e.g. between 2.1 and 8.3 MPa based on setting times between 4 and 72 hours)/hydrostatic testing	2,100	2,100	2,100	per pad	1,000	1,000	1,000	per pad	Over the lifetime of the pad	1,259	1,259	1,259	EPA (2010): internal mechanical integrity pressure test is approx. $ 2,100 per test per well, which is approx. €1500 in 2012 prices. With 8 wells per pad, the total cost is approx. €12,000 per pad. Assuming that test is carried out every five years, annualised cost is €1000 per play (2012 prices)	Testing integrity of wells would likely to reduce the risks of allowing the wells to develop potential leaks, therefore reduced likelihood of potential leakage of pollutants from wells
22b iii	Integrity testing at key stages in well development e.g. before/during/after all HF - mechanical integrity testing of equipment (MIT)	92,000	92,000	92,000	per pad	-	-	-	per pad	Over the lifetime of the pad	11,343	11,343	11,343	There are two methods considered. **Method 1:** EPA (2010) Test to demonstrate that wells have internal mechanical integrity (MI) (i.e., there is no significant leak in the casing, tubing, or packer) Internal mechanical integrity pressure test is $ 2,070 per test per well, which is approx. €1500 in 2012 prices. With 8 wells per pad, the total cost is approx. €12,000 per pad. **Method 2:** $25,000 to $30,000 (2012 prices) per test after the cement work is completed for the well. Assumed that the tests is done once (after the cement work) €19,000 to €23,000 per test per well, and €160,000 to €190,000 per pad in 2012 prices. Average is €170,000 per pad. Cost of measure is assumed to be an average of the costs from these two methods. Source: AMEC expert judgement based on practical experience of shale gas projects in the US (including Marcellus shale and others) transferred to the EU. Note costs have been converted in to € based on 2012 average exchange rate.	Testing integrity of wells would likely to reduce the risks of allowing the wells to develop potential leaks, therefore reduced likelihood of potential leakage of pollutants from wells
22b iv	Integrity testing at key stages in well development e.g. before/during/after all HF - Casing inspection test and log	350,000	350,000	350,000	per pad	-	-	-	per pad	Over the lifetime of the pad	43,152	43,152	43,152	EPA (2010): casing inspection log to determine the presence or absence of any casing corrosion: $2,070 per test + $4.15 per foot depth. Assumed that the tests is done once (after the cement work). It is assumed that the logging is done for the entire length of well (typically 3000 metres). Cost presented shows both the testing costs and the logging cost (which varies by depth).	Testing integrity of wells would likely to reduce the risks of allowing the wells to develop potential leaks, therefore reduced likelihood of potential leakage of pollutants from wells

Measure summary: 22d Search for and document potential leakage pathways (e.g. other wells, faults, mines)

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
22d	Search for and document potential leakage pathways (e.g. other wells, faults, mines)	-	-	-	per pad	-	-	-	per pad	N/A	-	-	-	Included in measure 3a x-a2 (Baseline - microseismicity including conceptual model of geological conditions) **Notes:** This measure would require literature review of the geological characteristics of the area. This is typically required in the UK. A 2-D assessment covering surface and near-surface area would be £5,000, which is equiv. to €6200 in 2012 prices. Leakage pathways and other sub-surface characteristics would require 3-D assessment and therefore would be more expensive. For this measure, it is assumed that the cost would be double the 2-D assessment. Source: AMEC expert judgement based on unconventional gas projects in the US (including Marcellus shale and others) transferred to the EU and experience of research and development of well design guidelines for unconventional gas the Environment Agency, England. EPA (2010) Appendix B suggests (p. 12) “simple fluid flow calculations” would require 36 hours of engineer labour per site, plus additional 12 hours per well. According to EPA, "modelling of fluid flow in the subsurface can be based on relatively simple, straightforward approaches that are not particularly data intensive, or can be extremely involved using sophisticated numerical reservoir". The costs noted here is for the simple calculation.	

Measure summary: 26d Development of conceptual model

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
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	-	-	-	per pad	N/A	3,300	4,300	per pad	Over the lifetime of pad	3,800	3,300	4,300	This measure is related to measure 3a x-a4 (Baseline - microseismicity including conceptual model of geological conditions: Complex modelling of fluid flows and migration (reservoir simulations). It is assumed that 10% of the modelling cost described in 3a x-a4 is the cost of upgrading the model with new information. It should be noted that measure 3a x-a4 has LOW and HIGH ambition, and therefore cost for this measure would depend on whether L or H has been selected in the policy option. Source: AMEC expert judgement based on experience of research and development of well design guidelines for unconventional gas the Environment Agency, England together with experience of the development of conceptual models for water resources.	

Measure summary: 26e Modelling of fracturing programme to predict extent of fracture growth based on best information

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
26e	Modelling of fracturing programme to predict extent of fracture growth based on best information	62,000	62,000	62,000	per pad	-	-	-	per pad	Over the lifetime of pad	7,644	7,644	7,644	Modelling natural fractures would be based on the Discrete Fracture Network (DFN) approach and include dynamic response (e.g. Hydro-shearing) to simulation. In shale gas, the model would include tensile fracture, the growth of which depends on the mechanical properties of the rock, in situ stress, applied forces and on leak off of fluids through the formation and natural fractures, using Finite Element Analysis (FEA) or Discrete Element Method (DEM). 3D fracture modelling integrated with geomechanics model would be approximately £50,000 (equiv. to approx. €62000 in 2012 prices). As input a larger data acquisition programme is needed of mechanical testing, mapping natural fractures from borehole image and/or core (covered under baseline conceptual model). Source: AMEC expert judgement based on experience of research and development of fracture modelling for unconventional and conventional gas plays.	By better understanding fracture formation, operators would be able to understand whether the exploration and/or development activities may lead to fracturing beyond the designated areas.

Measure summary: 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

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
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	-	-	-	per pad	10,000	10,000	10,000	per pad	N/A	10,000	10,000	10,000	See measure 3b xvii for geophone array cost which is assumed to already apply. Additional time cost of 32 hours per fracturing operation (assumed 8 weeks duration) of operator time = 32 x €39/h = approx. €1300 per well and €10,000 per pad.	

Measure summary: 29c Bunding of fuel tanks

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
29c	Bunding of fuel tanks	13,000	13,000	13,000	per pad	-	-	-	per pad	Over the lifetime of pad	1,603	1,603	1,603	Secondary containment should hold at least 110% of the largest tank volume. It should be noted that the entire well pad is built with secondary containment and that it might be easiest just to buy a dual-walled tank that has built in fire-safety measures. A stand alone secondary containment would be about $5000 for a 5000 gallon diesel tank (equiv. to some €4100 for a 20 cubic metre diesel tank) and $8000 for a 10,000 gallon tank (equiv. to some €6600 for a 40 cubic metre diesel tank). It would be more money for larger tanks or multiple tanks in one containment. For this measure, it is assumed that bunding would be needed for two 40m3 diesel tanks. Therefore cost of measure is approx. €13,000 Source: AMEC expert judgement based on practical experience of shale gas projects in the US (including Marcellus shale and others) transferred to the EU.	In cases where the fuel tanks overflow, bunding is designed to catch the overflow and therefore prevent leakage of diesel or other fuel used at the sited to the surrounding environment.

Measure summary: 29e Site reinstatement plan

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
29e	Site reinstatement plan	9,400	9,400	9,400	per pad	-	-	-	per pad	Over the lifetime of pad	1,159	1,159	1,159	Purpose of measure is to develop a reinstatement plan for the site following well closure and abandonment. Measure is the cost of the development of a plan to reinstate the site to its original condition. Assume one off cost of 160 hours @ €59/h (contractor) = approx. €9400 per pad for preparation of the plan. Costs of required reinstatement actions excluded.	Assurance that a plan is in place that sets out the required actions and programme to reinstate the site to its original condition considering the baseline and abandonment survey data.

Measure summary: 30c Use of closed loop system to contain drilling mud

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
30c	Use of closed loop system to contain drilling mud	160,000	160,000	160,000	per pad	Potential cost saving, see benefits.	-	-	per pad	Over the lifetime of pad	19,727	19,727	19,727	Closed-loop systems employ a suite of solids control equipment to minimise drilling fluid dilution and provide the economic and contained 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 farmed, hauled off or injected downhole. Source: AMEC expert judgement based on practical experience of shale gas projects in the US (including Marcellus shale and others) transferred to the EU.	Reduction in mud and waste volume. Obviates the need for an open pit and reduction in remediation/land reclamation costs. http://www.emnrd.state.nm.us/ocd/documents/2007_0110OGAP.pdf http://lubbockonline.com/business/2013-04-06/drought-increases-drilling-concerns

Measure summary: 30d Use of closed tanks for mud storage

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
30d	Use of closed tanks for mud storage	27,000	27,000	27,000	per pad	-	-	-	per pad	Over the lifetime of pad	3,329	3,329	3,329	In the US, a typical practice is to store mud in a lined pit, with features to protect wildlife and groundwater and prevent access from unauthorised persons. The mud is then pumped out of the pit by tanker trucks and hauled to the disposal facility. Closed loop system stores mud in tanks where solids can be separated at the pad and the water can be reused. Assuming a mud hauling truck can hold 130 barrels and provide enough storage to allow for a reasonable number of truck trips. Typical mud tanks are 500 barrel (equiv. to 80 cubic metre) tanks. Prices vary, but assumed to be €20000 per tank. Number of tanks required is estimated based on an AMEC estimate of waste storage requirements per foot of well drilled (0.47 to 0.63 cubic metres of mud generated per metre drilled). Assuming a well is 3000 metres deep, this indicates 21 tanks with 80 m^3 capacity are required per well. Assuming €20,000 per tank, cost per well is €420,000 to per well. It is assumed that the cost of using closed tanks for mud storage is 35% more expensive than the BAU, therefore the cost of measure relative to the BAU is approx. €110,000. Also assumed that these tanks would be used to store mud from 4 pads over their lifetime. Therefore the cost per pad is approx. €27,000.	If mud is stored in a tank rather than a lined pit, the risks of spillage is reduced.

Measure summary: 33b Use of tank level alarms

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
33b	Use of tank level alarms	26,000	26,000	26,000	per pad	-	-	-	per pad	Over the lifetime of pad	3,206	3,206	3,206	**Number of Tanks:** Assumed that tank alarms would be needed for storing mud, water, proppants and additives. Resource requirement per fracturing is based on illustrative play: some 1,650 m3 of mud, 13,500 m3 of water, 2,800 m3 of proppant, and 25% of 7,500 m^3 of flowback and 75 m3 of chemicals/additives. It was assumed that mud and proppant supply would be made once every 2-3 days in 80m^3 tanks; water supply would be daily in 80m^3 tanks; and the total amount of chemical/additives required per fracturing would be stored in 2 smaller tanks (40m^3). Based on these assumptions, 39 tanks are required (2 for mud; 8 for water, 4 for proppant, 23 for flowback and 2 smaller tanks for chemical/additives). **Tank Alarms:** Cost will vary depending on the type of tank alarms. Tank alarms can be very simple (a light/horn turns on when full/empty) or very complex (computer controlled valves, remote monitoring features, and systems that call operators when an alarm is tripped). A simple level sensor and controller is about $1000-$2000. Assumed $500 for installation. More expensive alarms with data logging features are $500-$2000. Assumed that an operator present at the site (but won't require to spend time to operate the alarm - once installed it is assumed to work automatically). For estimating the cost of this measure, an average figure of €2600 (inclusive of equipment and installation) was used per tank alarm. Based on 39 tanks and €2600 per tank alarm, the cost of this measure is approx. €100,000. These tanks are assumed to be used for 4 pads, therefore per pad cost is approximately €25,000.	In case the tanks get too full, alarm would ring and the operators would be able to prevent the overflow of chemicals or other liquid stored in the tank.

Measure summary: 33c Use of double skinned closed storage tanks

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
33c	Use of double skinned closed storage tanks	N/A	1,500	96,000	per pad	-	-	-	per pad	Over the lifetime of pad	6,010	185	11,836	**Low Ambition:** Assume double skinned storage tanks required for chemicals only. Standard tank capacity is 80m3. Given volumes of chemicals needed, assumed that 2 smaller 32m3 double skinned tanks are used instead of one 80m3 tank. Source: AMEC expert judgement. It is assumed these are 40% the price of 32 m^3 tanks. Costs (purchase only, not installed) for the fireguard tanks which are double walled, fire resistant, and ballistic proof are typically €10000 to €26500, per 80m3 tank. It is assumed 32 m3 tanks are 40% the price of 80 m3 tanks. (i.e. between €4,000 and €10,600). Therefore the cost of purchasing 2 doubled skinned 32m^3 tanks is approx. €15,000. Double-skinned tanks are approximately 350% more expensive than single-skinned tanks in the market place. Therefore additional costs of purchasing two small (32 m^3) doubled skinned tanks compared to single tanks are approximately €6000. It is assumed that the tanks will be used for 4 pads during their lifetime, therefore per pad costs is €1500. **High Ambition:** Assume double skinned storage tanks required for mud, flowback, proppant and chemical/additives storage (i.e. total 29 large and 2 small double skinned tanks required - see how the number of tanks required have been calculated in measure 33b). Same assumptions as above (doubled skinned tank costs for 80m^3 and 32m^3 capacities, 350% more expensive to purchase double-skinned tanks than single	Double skinned tanks provide greater structural rigidity and therefore is likely to be less damaged over time and thus provide better protection of the liquids and materials stored within.

Measure summary: 33d Spill kits available for use

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
33d	Spill kits available for use	4,000	4,000	4,000	per pad	-	-	-	per pad	Over the lifetime of pad	493	493	493	$1,000 per an average size spill kits. Assume 5 kits per site required. http://www.thecarycompany.com/containers/spill_control/spill_kits.html#cart Source: AMEC expert judgement based on practical experience of shale gas projects in the US (including Marcellus shale and others) transferred to the EU.	In case there is a spill, spill kit would provide useful tools to minimise the pollution arising from the leaked / spilled material.

Measure summary: 33e Berm around site boundary

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
33e	Berm around site boundary	79,000	79,000	79,000	per pad	-	-	-	per pad	Over the lifetime of pad	9,740	9,740	9,740	For a 2.24 hectare site, assuming a square block of 150m x 150m, the total length of a berm would be 600m. A berm 2 x 1 x 1 would be approximately £80 to £100 per metre^3 (this includes the cost of construction labour of 5 to 6 weeks to construct and the cost of construction). Assumed that 50% of this cost is labour, thus material cost is £40 to 50 per cubic metre, which is equiv. to approx. €66000 per berm construction material. Assumed 5.5 weeks of labour, which would cost 8 hours/day x 5 days/week x 5.5 weeks x €59 = €13,000. Total costs are thus €79,000 per berm construction per pad. Source: AMEC expert judgement based on quant surveyor data bill of quantities.	Berm around site boundary is likely to help containing any spilled liquid (if happens) to be contained within the boundary set by the berm.

Measure summary: 33f Impervious site liner under pad with puncture proof underlay

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
33f	Impervious site liner under pad with puncture proof underlay	240,000	240,000	240,000	per pad	-	-	-	per pad	Over the lifetime of pad	29,590	29,590	29,590	Assumes that a puncture proof geotextile membrane is used to cover the entire area of a well pad (assumed 2.24 hectare). Material and planting cost is assumed to be approximately €9.75 per square metre. Accounting for 10% unmeasured items, the cost for this measure is approximately €240,000 per well pad.	

Measure summary: 33g Collection and control of surface runoff

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
33g	Collection and control of surface runoff	41,000	41,000	41,000	per pad	13,000	13,000	13,000	per pad	Over the lifetime of pad	18,055	18,055	18,055	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. Operators include stormwater drainage system in site construction and include oil water separator system. Cost could be: - additional construction costs (minor) - oil water separator system.	Assurance that leaks and spills will drain to a single point enabling and facilitating effective management and control and hence increasing ability to avoid pollution incidents, particularly to surface water and land (soil).

Measure summary: 33i Good site security

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
33i	Good site security	40,000	40,000	40,000	per pad	14,000	14,000	14,000	per pad	Over the lifetime of pad	18,932	18,932	18,932	Applicable per site. Operators would need to select and pay for site security infrastructure and operatives. Operators would be required to ensure that the site is protected properly to prevent vandalism that may lead to pollution from damaged equipment/infrastructure. Capital Costs: - 2 metre high metal security fencing supplied and installed on 3,000 metres site perimeter, plus supply and installation of two gates. Operating Costs: - Assumed 10% of initial fence cost for maintenance. Annual cost of site security guard conducting one walk round per 24 period, of one hour duration in each case. Based on 'operative wage rates'. Assumes security guard is responsibly for several well pads. Centrally monitored CCTV system would be an alternative; this would depend on the density/geographical location of well pads and has not been quantified.	Assurance that the risk of pollution stemming from vandalism (e.g. damage to pollution control infrastructure, the causing of leaks and discharges to the environment) would be minimised/prevented.

Measure summary: 38b Demand profile for water

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
38b	Demand profile for water	13,000	13,000	13,000	per pad	-	-	-	per pad	Over lifetime of the pad	1,603	1,603	1,603	Two estimates have been considered: [1] Based on time incurred (between 40 and 80 consultant hours) to establish a demand pattern for a 'field' in China. In the example given the Client (an oil and gas firm) had completed some preparatory work (identifying the number of wells, pad locations, drilling sequence, water consumption per unit operation (pad construction, drilling, fracking, etc.)). That information was used to established flow patterns – peak and average flow volumes under a variety of scenarios throughout the course of the project. Hourly price is based on €59 per hour and assumed external consultant would compete the work. Average of 60 consultant hours is used for the cost estimates. [2] Estimate of between $10,000 to $50,000 for water demand modelling (if required); based on a project example from the United States. In the US it is the operators responsibility to identify water to use in field production activities. The majority of work in the western US related to water rights. In the examples given, it is common for simple calculations to be made to align supply with demand. Modelling to assess water supply is likely limited, from $10,000 to up to $50,000. Those consulted were not aware of any large-scale detailed modelling that has been used specific to oil and gas water supply. Relativity simple, low cost models are generally used for water supply assessments. Average cost is quoted as a cost estimate. Source: AMEC expert judgement based on practical experience of shale gas projects in the US (including Marcellus shale and others) transferred to the EU.	The study provides an informed prediction of the water demand/extraction (from both ground and surface water) during the wells operational life.

Measure summary: 38d Reuse of flowback and produced water for fracturing

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
38d	Reuse of flowback and produced water for fracturing	5,000	5,000	5,000	per pad	-	-	-	per pad	Over lifetime of the pad	616	616	616	Assumed chemical oxidation as a minimal treatment of flowback/produced water for reusing. This would be equivalent to €4,000 to €14,000 per well. Cost savings from reusing the waste is approximately €4,000. Therefore the net cost of the measure is €0 to €10,000. Average cost of €5,000 is used as a cost estimate.	Reduction in water demand and associated environmental impacts and water scarcity issues. (see below for summary). Potential impacts: water extraction can result in lowering the water table; dewatering aquifers and change in water quality (e.g. chemical contamination from mineral exposure to aerobic environment; bacterial growth due to lower water table; release of biogenic methane into superficial aquifers; upwelling of lower quality water or substances into aquifer; subsidence and destabilisation of geology. There is a potential cumulative effect of large numbers of operations, particularly in drought and dry periods but also in wet regions where there are stresses within existing water supplies due to substantial demands or limited infrastructure).

Measure summary: 51c Noise screening instalation

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
51c	Noise screening installation: (i) screen drilling and fracturing rigs with noise barrier / enclosure; (ii) acoustic fencing around the site perimeter.	219,000	219,000	219,000	per pad	13,400	13,400	13,400	per pad	Over lifetime of the pad	40,401	40,401	40,401	Combined for presentation	
51c i	Noise screening installation: (i) screen drilling and fracturing rigs with noise barrier / enclosure; (ii) acoustic fencing around the site perimeter.	130,000	130,000	130,000	per pad	13,000	13,000	13,000	per pad	Over lifetime of the pad	29,028	29,028	29,028	This is for submeasure (i). For screening on rig: $20,000 (2010 prices), which is equiv. to €16,000 in 2012 prices. Assumed price is per rig (= per well). Assuming 8 wells per pad, the cost is approx. €130,000 per pad. Estimated cost of noise barrier/enclosure on one drilling/fracturing rigs. We have assumed size of each rig within an illustrative play is constant. Operational cost is assumed to be 10% of capital cost Source: Golden Rules for a Golden Age of Gas. International Energy Agency Page 55.	Noise/sound attenuation to mitigate adverse impact for population and wildlife/habitats.
51c ii	Noise screening installation: (i) screen drilling and fracturing rigs with noise barrier / enclosure; (ii) acoustic fencing around the site perimeter.	89,000	89,000	89,000	per pad	400	400	400	per pad	Over lifetime of the pad	11,373	11,373	11,373	This is for submeasure (ii). Acoustic fencing required around the site perimeter. Material £77 per linear metre. Labour £40 per linear metre. I.e. total c. £120 per linear meter of fencing. Assuming average pad plot size is 2.24ha. Costs likely to increase if the ground in uneven/sloped. Costs are for a 2 metre high acoustic fence, per linear metre. Operational cost is assumed to be 5% of capital cost and occurs every 5 year. Annualised cost over the lifetime of a pad (10 years) is approx. €400. Source: AMEC expert judgement based on experience of noise mitigation of industrial sites in the UK. Landscaping (mounds) may be required for larger/more intrusive developments. Costs for this are entirely place specific, influenced by the distance material has to travel to the site.	

Measure summary: 55c Ground motion prediction models to assess the potential impact of induced earthquakes

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
55c	Ground motion prediction models to assess the potential impact of induced earthquakes	11,000	11,000	11,000	per pad	-	-	-	per pad	Over lifetime of the pad	1,356	1,356	1,356	The following already assumed to be covered by measures 3a x (Baseline - microseismicity including conceptual model of geological conditions): i) Obtain and analyse seismic history ii) conduct 3D seismic survey to identify faults and fractures Assume modelling costs of 190hx€59/h = approx. €11000.	Likely to avoid or minimise earthquakes or mitigate impact/effects of these.

Measure summary: 55d Microseismicity monitoring and management requirements during operations

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
55d	Microseismicity monitoring and management requirements during operations	-	-	-	per pad	N/A	1,200	-	per pad	Over lifetime of the pad	600	1,200	-	LOW AMBITION: Cross ref. 3b xvii for geophone array cost which is assumed to already apply. Linked also to tasks carried out under measures 3a x (baseline microseismicity and geological conceptual model). Additional time cost of 32 hours per fracturing operation (assumed 8 weeks duration) of operator time = 32 x €39/h = approx. €1200. HIGH AMBITION: Cessation of activities fracturing if specified induced seismicity activity is detected (traffic light system). Qualitative assessment is that costs will be loss of productivity/delay to proceeding if fracturing is stopped.	Likely to avoid or minimise earthquakes or mitigate impact/effects of these.

Measure summary: 59a Traffic impact assessment including consideration of noise, emissions and other relevant impacts

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
59a	Traffic impact assessment including consideration of noise, emissions and other relevant impacts	15,000	15,000	15,000	per pad	-	-	-	per pad	Over lifetime of the pad	1,849	1,849	1,849	Two methods have been considered: [1] Assessments typically cost between £7,000 and £10,000 for a single land use. More complex/larger assessment can cost up to £30,000. Note cost estimate excludes noise and emissions aspects. The assessment considers route capacity, volumes/movements required over operational lifetime. Average cost is used. Source: AMEC expert judgement based on experience of traffic impact assessment for developments in the UK. [2] Estimated at between £8,000 and £10,000. Costs have been provided for complete impact assessment (£15,000). Average cost is used. Source: AMEC expert judgement based on experience of traffic impact assessment for developments in the UK. Costs for the impact assessment (excluding baseline) baseline element has been estimated based on the proportion of total work judged to be required at impact assessment stage. It assumes detailed/bespoke transport modelling is not required. An average cost of €15000 has been assumed for this measure.	Traffic volumes are estimated and planned for and adverse impacts on existing settlements/traffic flows are mitigated.

Measure summary: 59b Transport management plan (including consideration of available road, rail, waterway infrastructure)

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
59b	Transport management plan (including consideration of available road, rail, waterway infrastructure)	4,500	4,500	4,500	per pad	-	-	-	per pad	Over lifetime of the pad	555	555	555	Two methods have been considered: [1] Assessments typically cost between £2,500 and £4,000. Assumes the management plan would need to be scoped with relevant highway authority. For larger/more complex operations, cost would be higher, but this is place/context specific and depends on number of movements, clustering of wells and road capacity /settlements in vicinity of well/field. Source: AMEC expert judgement based on experience of traffic management plans for developments in the UK. [2] Between £3,000 and £5,000. Includes consideration of measures such as wide loads/removal of any vegetation, escorts of unusual cargos by Police and/or contractor, liaison with Police/Highways authority. Estimate of an assessment for a typical well pad. Costs have been provided for complete impact assessment (£15,000). Source: AMEC expert judgement based on experience of traffic management plans for developments in the UK. Costs for the management plan (i.e. excluding baseline and impact assessment) has been estimated based on the work activities required. An average cost of €4500 has been assumed for this measure.	Efficient use is made of existing transport infrastructure. Expected traffic volumes, patterns and any additional traffic management measures required are identified and implemented.

Measure summary: N06 Operations to be subject to an integrated permit

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
N06	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	21,000	21,000	21,000	per pad	2,000	2,000	2,000	per pad	Over lifetime of the pad	4,589	4,589	4,589	Cost estimate is based on the cost of applying for and maintaining an IED permit. Note the cost of monitoring and associated technical measures are addressed elsewhere. Source: AMEC (2013): Collection and Analysis of Data to support the Commission in reporting in line with Article 73(2)(a) of Directive 2010/75/EU on industrial emission on the need to control emissions from the combustion of fuels in installations with a total rated thermal input below 40MW. The figures used derive from the IED Impact Assessment, Page 158,160 and 161. These relate to plants using 20-50MWth. In the study noted above, the costs were decreased by 40% to reflect costs for 1-5MWth plants - in line with the predicted energy/fuel use in the illustrated play. Note annual costs have been divided by three, reflecting comments raised during consultation/client comment in the above study. Source: AMEC expert judgement.	Ensure compliance with MS regulatory regime.

Measure summary: 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)

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
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)	80,000	80,000	80,000	per pad	-	-	-	per pad	Over lifetime of the pad	9,863	9,863	9,863	Operators would be required to develop and maintain contingency plans to address foreseeable impacts. This will require: risk identification (5 days of consultant time); evaluation of risks (15 days) followed by development of necessary contingency plans (50 days); Consultation and testing with Competent Authority and Emergency Services (50 days) Defining approach to investigative approach and corrective action (50 days) and Reporting (10 days). Examples are preparation of contingency plans to manage degradation/damage to well construction; contingency plans for wastewater treatment/management if the planned management route becomes unavailable. Operators would be required to carry out a risk assessment and evaluation of risks to determine events that will require contingency actions. Contingency plans will need to be developed as appropriate and put in place. Costs would be: - assessment/evaluation of foreseeable risks - development and maintenance of a contingency plan responding to risks. Ongoing monitoring requirements associated with this measure are discussed elsewhere.	Potential risks to operating conditions are identified and suitable contingency plans made and in place to enable rapid and suitable response to minimise/remove environmental risk.

Measure summary: N13 Member States carry out SEA to set up plans/programmes setting the framework for unconventional gas before granting concessions

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
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 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.	77,000	77,000	77,000	per pad	-	-	-	per pad	Over lifetime of the pad	9,493	9,493	9,493	Preparation of SEA by external consultant. Cost estimate is based on recent experience in preparation of SEA project of major licensing plan for Hydrocarbons for a Member State. Source: AMEC expert judgement based on extensive experience of performing major SEAs in the UK for policies and programmes. Note this excludes the administrative cost of considering the merits of individual applications/ EIA submissions. This will be considered separately.	High Level assessment to identify systemic risks at Member State or concession level .

Measure summary: N15 Mandatory EIA for all projects expected to involve hydraulic fracturing, before exploration starts

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
N15	Mandatory EIA for all projects expected to involve hydraulic fracturing, before exploration starts	64,000	64,000	64,000	per pad	-	-	-	per pad	Over lifetime of the pad	7,891	7,891	7,891	Cost of preparation of EIA cost (once) prior to exploration. Low end estimates are based on average costs for EIA, taken from the 'European Commission. Commissions Staff Working Paper. Impact Assessment, accompanying the document 'Proposal for a Directive of the European parliament and of the Council amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment. (COM(2012 628 final).' High end costs are estimated based on experience of preparation of costs for EIA assessments. Precise costs will depend on scope, and location. Source: AMEC expert judgement based on experience of carrying out EIAs for a variety of major and complex industrial and other developments in the UK. Note this excludes the administrative cost of considering the merits of individual applications/ EIA submissions. This will be considered separately.	Systemic identification of environmental impacts, assessment of their scale and mitigation measures required. EIA can help ensure sustainable design of projects/operations from an early stage.

Measure summary: N16 i Mandatory EIA (i) after initial phase of well exploration and before first test fracturing, and (ii) before production commences

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
N16 i	Mandatory EIA (i) after initial phase of well exploration and before first test fracturing, and (ii) before production commences	64,000	64,000	64,000	per pad	-	-	-	per pad	Over lifetime of the pad	7,891	7,891	7,891	Cost of preparation of EIA cost (once) prior to exploration. Low end estimates are based on average costs for EIA, taken from the 'European Commission. Commissions Staff Working Paper. Impact Assessment, accompanying the document 'Proposal for a Directive of the European parliament and of the Council amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment. (COM(2012 628 final).' High end costs are estimated based on experience of preparation of costs for EIA assessments. Precise costs will depend on scope and location. Savings may be achieved where previous EIA (See N15) has been undertaken relatively recently. Source: AMEC expert judgement based on experience of carrying out EIAs for a variety of major and complex industrial and other developments in the UK. Note this excludes the administrative cost of considering the merits of individual applications/ EIA submissions. This will be considered separately.	Systemic identification of environmental impacts, assessment of their scale and mitigation measures required. EIA can help ensure sustainable design of projects/operations from an early stage.

Measure summary: N17 Assessment of whether full project is likely to have significant effects on the environment during prospecting phase

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
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/prospecting and taking account of the entire project)	25,000	25,000	25,000	per pad	-	-	-	per pad	Over lifetime of the pad	3,082	3,082	3,082	Cost of preparation of an EIA Screening and Scoping Report. Source: AMEC expert judgement based on experience of carrying out EIAs for a variety of major and complex industrial and other developments in the UK. Note this excludes the administrative cost of considering the merits of individual applications/ EIA submissions. This will be considered separately.	Identification of environmental impacts that are likely or have the potential to be significant and hence require more detailed assessment in a Full EIA. The scoping assessment can reduce the costs and complexity of the full EIA and ensure it is focussed on the key environmental impacts.

Measure summary: N20 Environmental management system accreditation for unconventional gas installation operators

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
N20	Environmental management system accreditation for unconventional gas installation operators	25,000	25,000	25,000	per pad	3,000	3,000	3,000	per pad	Over lifetime of the pad	6,082	6,082	6,082	Cost of development and maintenance of EMS per site. One off costs: Requires initial audit, post audit design and support, health check, staff training, internal audit and compliance check. A total of 43 engineer days required. Allowance has been made for certification cost, which includes application fee. Operational Costs: Based on estates of costs of ten year compliance, including certification application and audits for 10 years, this figures has been annualised. Whilst this would apply over the lifetime of the well, it is likely requirements will decrease once well is operational and if using closed systems. Source: AMEC expert judgement based on experience of similar requirements for a variety of industrial and public sector clients globally. Based on an assumed average of 20 'Annual Job Equivalent' (assumed to be the same as Full Time Equivalent), jobs required per site taken from the Socio-economic chapter of Environmental Statement of the Jonah Infill Drilling Project, Table 4.17 page 4-88. US Department of Interior, Department of Land Management. / multisitehttp://www.blm.gov/pgdata/etc/medialib/blm/wy/information/NEPA/pfodocs/jonah.Par.6205.File.dat/10c	Environmental Risk and management approaches are integrated into all operations; staff appropriately trained. Members of public are given confidence that contractors are appropriately trained and environmental standards enforced.

Measure summary: N27 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

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
N27	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	-	-	-	per pad	60	60	60	per pad	Over lifetime of the pad	60	60	60	Cost for collection/collation of monitoring data and publication of annual reports. Hours/days required are assessed below, by task. Reaction will be entirely contingent on nature of problem and has not been quantified. Costs to include: - Number of exploration and exploitation wells drilled, active, abandoned. - Volume of gas extraction - Ground/surface water use - Any environmental incidents, spillages, blow outs etc, environmental effects and remedial action - traffic movements - public complaints Assumed that it takes approx. 28 days of work by competent authority per year (equiv. to some €16,000). This is done at the concession level, so the cost per pad is some €60.	Systemic risks from all activities monitored.

Measure summary: N30 The European Commission to develop further criteria/guidance for the assessment of environmental impacts from unconventional gas

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
N30	The European Commission to develop further criteria/guidance for the assessment of environmental impacts from unconventional gas	200	200	200	per pad	-	-	-	per pad	Over lifetime of the pad	25	25	25	Update to EIA Guidance documents to cover Scoping; Screening and EIA. Envisage a separate specific document setting out the key issues that will need to be considered under the broad headings considered in this study. Previous examples are c20 pages, it is envisaged given the prominence and complexity of potential environmental effects arising from UG, that the guidance would be more detailed. Fees for private consultants to prepare guidance related to Socio-economic impacts related to the REACH regulation have been some €150,000. It is likely that given the requirements , that between 60 and 100 days of EC officer time would be required - between €45,000 and €57,000. This is done at the concession level, so the cost per pad is some €200. http://ec.europa.eu/environment/eia/eia-guidelines/g-review-full-text.pdf Costs to include: - Drafting of guidance - Internal consultation - publication and dissemination	Clarify on scope of EIAs and EC expectations of developers and their consultants when preparing EIAs; likely to reduce costs and avoid delays in consideration/resubmission of EIAs and applications and will ensure that EIA assessments are made on a consistent (hence comparable) and accurate basis.

Measure summary: N31 Inspections by Competent Authorities during all stages of development (e.g. of well completion reports and environmental risk management and controls)

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
N31	Inspections by Competent Authorities during all stages of development (e.g. of well completion reports and environmental risk management and controls)	-	-	-	per pad	10	10	10	per pad	Over lifetime of the pad	10	10	10	A total of five days inspector time per site, per year has been assumed. Based on annual time estimate for completion of EMS certification audit by external auditor, which is approx. €1500. This is done at the concession level, so the cost per pad is some €10.	Adherence to environmental standards enforcement against non compliance , protection from environmental accidents. Enhances public confidence in process.

Measure summary: N34 Public authorities produce an underground regional impact assessment to optimise resource allocation between unconventional gas and other underground resources (e.g. geothermal energy)

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
N34	Public authorities produce an underground regional impact assessment to optimise resource allocation between unconventional gas and other underground resources (e.g. geothermal energy)	250	250	250	per pad	-	-	-	per pad	Over lifetime of the pad	31	31	31	The same costs has been used as low end estimate for the cost of preparation of a Strategic Environmental Assessment (SEA) by external consultant. It is likely that the public authorities would commission this externally. The cost estimate is based on recent experience in preparation of SEA project of major licensing plan for Hydrocarbons for a Member State. Source: AMEC expert judgement based on extensive experience of performing major SEAs in the UK for policies and programmes. The cost allows some 140 external consultant days or 200 CA staff days. This would be some €62,000 per concession, therefore per pad cost is approx. €250.	Enables strategic overview of resources and maximises national resource efficiency.

Measure summary: N40 Member State Competent Authorities provide a map of planned and existing exploration, production and abandoned well locations

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
N40	Member State Competent Authorities provide a map of planned and existing exploration, production and abandoned well locations	-	-	-	per pad	20	20	20	per pad	Over lifetime of the pad	20	20	20	Costs for competent authority of drawing together information from all well applications and updating to reflect operational changes. Assume annual reporting/updating. Costs include: - Collection/collation of data - GIS presentation. Costs based on: Hourly cost of CA Staff (€41) Assumes 10 days data entry and 3 days for GIS presentation. Assumed that this is done per concession.	Accessible information for operators and the general public to observe geographical concentration and scale of activity. Potential to avoid drilling into closed wells with associated seismic and environmental contamination implications.

Measure summary: N41 Member State Competent Authorities provide information on the licences and permits of operators involved in unconventional gas exploration and production

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
N41	Member State Competent Authorities provide information on the licences and permits of operators involved in unconventional gas exploration and production	-	-	-	per pad	30	30	30	per pad	Over lifetime of the pad	30	30	30	Costs for competent authority of drawing together information from all well applications and publishing the relevant details on website. Assume negligible website construction required. Assume 0.5 day per week devoted to collating this information. This is done at the concession level.	Accessible information for the general public, NGOs and other organisations on regulatory restrictions. Supports growth of public confidence in regulatory regime and risk management and operator transparency.

Measure summary: N55 Conduct 2D seismic survey to identify faults and fractures

Ref	Measure description	One-off / capital costs (€)				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
N55	Conduct 2D seismic survey to identify faults and fractures	14,000	14,000	14,000	per pad	-	-	-	per pad	Over the lifetime of the pad	1,726	1,726	1,726	This measure allows operators to identify faults and fractures using a 2D seismic survey. It is assumed that the survey is done on two 2D seismic lines (one north to south and the other east to west) for a given area. Cost of $7,500 per mile plus $500 to 1,000 per mile for processing in 2011 prices, presented by Indiana Oil and Gas Association in the US (http://www.inoga.org/archive/2011/2011_Presentations/CorySeismicPresentation.pdf), has been assumed and this is approx. €3,800 per km in 2012 prices. Based on an underground area of 3.2 km^2 per pad (i.e. 1.8 km x 1.8 km), the cost of measure is approx. €14,000 per pad.	Systemic identification of environmental impacts, assessment of their scale and mitigation measures required. EIA can help ensure sustainable design of projects/operations from an early stage.

Measure summary: CAL1 Require hydraulic fracturing specific chemical safety assessment

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
CAL1	Require hydraulic fracturing specific chemical safety assessment (through REACH) addressing specific risks associated with unconventional gas and associated pathways for exposure of the environment and humans via the environment (including routes via underground pathways). Appropriate risk management measures to be specified in this assessment.	800	800	800	per pad	-	-	-	per pad	5	180	180	180	Assumed cost to produce a HF-specific chemical safety assessment is €11,800 to €23,600 and this is required for 12 substances per play (based on FracFocus data). Assessment/costs would not necessarily need to be repeated for all other plays, although substances used differ so there would be some degree of additional costs. Unit price is based on internal knowledge of cost of (part of a) CSA and hourly consultancy wage rates based on Eurostat data. Assumes a greater level of detail in assessment would be required compared to BAU in CSRs which often give very generic exposure scenarios. Cost per substance is for a downstream user CSA based on study for DG Enterprise.	Assurance that chemicals used do not pose unacceptable risks to health or the environment under reasonably foreseeable conditions of use.

Measure summary: CAL2 Develop a peer-reviewed EU-level exposure scenario / SpERC for HF for different chemical types.

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
CAL2	Develop a peer-reviewed EU-level exposure scenario / SpERC for HF for different chemical types.	200	200	200	per pad	-	-	-	per pad	Over lifetime of the pad	25	25	25	It is assumed that the UG industry would develop the SpERC. Cost estimates based on estimated time (50 to 150 days) and associated costs (€22,000 to €66,000 of external consultant fees based on hours needed for the work) to develop a specific environmental release category for chemical types / categories used in HF, with subsequent peer review. The output of this analysis would be used for the EU: in order to present this cost per pad, the cost is assumed to be per concession, therefore is divided by 250 well pads per concession. Does not include actual implementation of the SpERC in substance-specific chemical safety assessment (see CAL3).	Intended to ensure a sufficient degree of rigour and consistency in assessment of the safety of chemicals used in HF across operators and across different substances.

Measure summary: CAL3 CAL2 to be implemented in CSAs for chemicals used in HF and any deviations explained

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
CAL3	CAL2 to be implemented in CSAs for chemicals used in HF and any deviations explained	200	200	200	per pad	-	-	-	per pad	5	45	45	45	CAL1 already includes the cost of conducting a chemical safety assessment for specific chemicals. The cost here relates solely to the additional costs of applying the EU-level exposure scenario / SpERC from CAL2 and justifying any deviations from this. Assuming it takes 5 to 15 days of work by external consultants per substance, the analysis for 12 substances is between €27,000 and €80,000. This work would be done per concession (with 250 well pads), so the cost per pad is relatively small. CAL2 assumes that the UG industry would develop a SpERC / exposure scenarios for different chemical types for use in chemical safety assessment (as for example many industry sector associations have done). The costs have been built up using a technical/engineering consultancy wage rate. CAL2 assumes that there would be peer review of this, which could be done by other industry staff or by the authorities. CAL3 then assumes that the UG industry (i.e. operating companies) would be required to use the SpERC / exposure scenario in developing their chemical safety assessments (for each substance used, specific to each play/concession). This is therefore to be done by the industry, but it's also worth noting that REACH provides for evaluation by competent authorities (this would be part of the BAU, however).	Intended to ensure a sufficient degree of rigour and consistency in assessment of the safety of chemicals used in HF across operators and across different substances.

Measure summary: CAM1 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

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
CAM1	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	1,300	1,300	1,300	per pad	-	-	-	per pad	5	292	292	292	Costs are based on CAL1 for estimate of costs to undertake chemical safety assessment per substance. It is assumed that there could be 1-2 relevant transformation products on average per individual substance used in HF and for which it is considered relevant to assess potential environmental risks. This number is indicative based on past experience with REACH CSA dossiers for other substances/uses and is not based on a review of all potential transformation products of specific chemicals used in a HF context (assumed 25 to 50 days of external consultant work for 12 substances for 1 to 2 transformation products, which would be €330,000 per study). This work would be done per concession (with 250 well pads), so the cost per pad is relatively small.	Ensures that operators are required to demonstrate not only the safety of the chemicals that they use in HF but also the safety of the potential transformation products in an underground context.

Measure summary: CSL3 Negative list of named substances that must not be used in UG extraction (alternative to two measures CSL1 and CSL2)

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
CSL3	Negative list of named substances that must not be used in UG extraction (alternative to two measures CSL1 and CSL2)	200	200	200	per pad	400	400	400	per pad	5	445	445	445	Based on assumed administrative cost to authorities to review 5-10 substances per year for inclusion on such a list, with initial set up time requirements in person-days. These are purely indicative and the actual costs could vary significantly depending on the form of the list, extent of technical review undertaken, peer review, challenges, etc. The output of this analysis would be used for the EU: in order to present this cost per pad, the cost is assumed to be per concession, therefore is divided by 250 well pads per concession. Quantified cost does not include costs to operators of not using chemicals on this list (e.g. reduced productivity implications from using less technically efficacious but safer substances). Costs are based entirely on the consultants' own judgement as no comparable cost data have been identified.	Intended to ensure that those chemicals with the most significant hazards / potential risks are not used, hence reducing the potential for pollution of groundwater, surface water, etc.

Measure summary: CSM2 Positive list of substances expected to be safe under EU UG extraction conditions and require operators to only use substances on this positive list

Ref	Measure description	One-off / capital costs				Operating/ongoing costs (€ per year unless specified elsewhere)				Expected measure lifetime (amortisation period)	Annualised Compliance Cost (€ per pad)			Summary of key assumptions for cost estimates	Benefits
		MIDDLE	LOW	HIGH	Unit	MIDDLE	LOW	HIGH	Unit		MIDDLE	LOW	HIGH		
CSM2	Positive list of substances expected to be safe under EU UG extraction conditions and require operators to only use substances on this positive list	200	200	200	per pad	-	-	-	per pad	5	45	45	45	Based on assumed administrative cost to authorities to review 5-10 substances per year for inclusion on such a list, with initial set up time requirements in person-days. These are purely indicative and the actual costs could vary significantly depending on the form of the list, extent of technical review undertaken, peer review, challenges, etc. The output of this analysis would be used for the EU: in order to present this cost per pad, the cost is assumed to be per concession, therefore is divided by 250 well pads per concession. Quantified cost does not include costs to operators of only using chemicals on this list (e.g. reduced productivity implications from using less technically efficacious but safer substances). Costs are based entirely on the consultants' own judgement as no comparable cost data have been identified.	Intended to ensure that only those chemicals for which it has been shown that use is expected to be safe under typical conditions in the EU are used in HF.

Inflation, FX

Discount rate 4%

HICP (2005 = 100) - annual data (average index and rate of change) [prc_hicp_aind]

Last update	16.01.13
Extracted on	14.02.13
Source of Data	Eurostat
Short Description	Short Description is not available
INFOTYPE	Annual average index
COICOP	All-items HICP

GEO/TIME	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
European Union (27 countries)	95.59	97.77	100.00	102.31	104.73	108.56	109.63	111.91	115.38	118.43

Conversion factor to 2012	1.24	1.21	1.18	1.16	1.13	1.09	1.08	1.06	1.03	1.00

Average monthly BID rates @ +/- 0%
www.oanda.com/currency/historical-rates/

End Date	USD/EUR	GBP/EUR
31/12/2012	1.3105	0.8126
30/11/2012	1.2827	0.8033
31/10/2012	1.2968	0.8065
30/09/2012	1.2854	0.7987
31/08/2012	1.2384	0.7884
31/07/2012	1.2309	0.7889
30/06/2012	1.2534	0.8064
31/05/2012	1.284	0.8047
30/04/2012	1.3169	0.823
31/03/2012	1.3212	0.8349
29/02/2012	1.322	0.8367
31/01/2012	1.2893	0.8314
31/12/2011	1.3184	0.8451
30/11/2011	1.3587	0.8582
31/10/2011	1.37	0.8695
30/09/2011	1.3804	0.8722
31/08/2011	1.4342	0.8759
31/07/2011	1.4306	0.8861
30/06/2011	1.4382	0.886
31/05/2011	1.434	0.8765
30/04/2011	1.4435	0.8829
31/03/2011	1.4001	0.8661
28/02/2011	1.3645	0.8465
31/01/2011	1.3353	0.8474
31/12/2010	1.3213	0.8465
30/11/2010	1.3695	0.8566
31/10/2010	1.3893	0.8757
30/09/2010	1.303	0.8374
31/08/2010	1.2912	0.824
31/07/2010	1.2756	0.8353
30/06/2010	1.2213	0.8291
31/05/2010	1.262	0.858
30/04/2010	1.3442	0.877
31/03/2010	1.3578	0.9015
28/02/2010	1.368	0.8754
31/01/2010	1.4281	0.8837
31/12/2009	1.4603	0.8993
30/11/2009	1.4895	0.8979
31/10/2009	1.4807	0.9162
30/09/2009	1.4548	0.891
31/08/2009	1.4254	0.8612
31/07/2009	1.407	0.8601
30/06/2009	1.4012	0.8569
31/05/2009	1.3632	0.8858
30/04/2009	1.3205	0.8986
31/03/2009	1.3034	0.9174
28/02/2009	1.2813	0.8871
31/01/2009	1.3355	0.9218
31/12/2008	1.3467	0.9044

Annual Average

	USD/EUR	GBP/EUR
2012	1.285958	0.811292
2011	1.392325	0.8677
2010	1.327608	0.85835
2009	1.393567	0.891108
2008	1.470817	0.795658
2007	1.37	0.684258
2006	1.255408	0.681642
2005	1.2453	0.683758
2004	1.243458	0.678308

Inflation, FX

30/11/2008	1.2708	0.8274
31/10/2008	1.336	0.7859
30/09/2008	1.4394	0.7983
31/08/2008	1.4994	0.7915
31/07/2008	1.578	0.793
30/06/2008	1.557	0.7912
31/05/2008	1.5559	0.7914
30/04/2008	1.5761	0.7948
31/03/2008	1.5484	0.7738
29/02/2008	1.4722	0.7499
31/01/2008	1.4699	0.7463
31/12/2007	1.4558	0.7209
30/11/2007	1.4666	0.7075
31/10/2007	1.4225	0.696
30/09/2007	1.3884	0.6876
31/08/2007	1.363	0.6773
31/07/2007	1.3704	0.6745
30/06/2007	1.3417	0.6759
31/05/2007	1.3521	0.6812
30/04/2007	1.3498	0.6796
31/03/2007	1.3236	0.6797
28/02/2007	1.3064	0.6672
31/01/2007	1.2997	0.6637
31/12/2006	1.3198	0.6724
30/11/2006	1.286	0.6735
31/10/2006	1.2615	0.6729
30/09/2006	1.2737	0.6748
31/08/2006	1.2802	0.6768
31/07/2006	1.2703	0.6882
30/06/2006	1.267	0.6861
31/05/2006	1.2762	0.6833
30/04/2006	1.2243	0.6941
31/03/2006	1.2019	0.6888
28/02/2006	1.1951	0.683
31/01/2006	1.2089	0.6858
31/12/2005	1.1852	0.6789
30/11/2005	1.1789	0.6793
31/10/2005	1.2033	0.6816
30/09/2005	1.2272	0.6774
31/08/2005	1.2294	0.6861
31/07/2005	1.2041	0.6869
30/06/2005	1.2168	0.6687
31/05/2005	1.2695	0.6835
30/04/2005	1.2942	0.6827
31/03/2005	1.3204	0.6926
28/02/2005	1.3005	0.6891
31/01/2005	1.3141	0.6983
31/12/2004	1.3395	0.6941
30/11/2004	1.3002	0.699
31/10/2004	1.2507	0.6917
30/09/2004	1.2205	0.6807
31/08/2004	1.2198	0.6691
31/07/2004	1.2274	0.6656
30/06/2004	1.2147	0.6637
31/05/2004	1.1999	0.6712
30/04/2004	1.2011	0.6643
31/03/2004	1.2265	0.671
29/02/2004	1.2616	0.6768
31/01/2004	1.2596	0.6925
Period Average	1.3316	0.7725
Period Low	1.1789	0.6637
Period High	1.578	0.9218

Wage

Wage calculations

Sources of information: Eurostat

Dataset:	Structure of labour costs (%) - NACE Rev. 2 [lc_an_struc_r2]	
	Mean hourly earnings by sex, economic activity and occupation [earn_ses10_47]; Structure of earnings survey 2010	
	Mean monthly hours paid by sex, economic activity and occupation [earn_ses10_50]	
Extracted on	07.03.13	
SIZECLAS	10 employees or more	
ISCO08	Managers	
NACE_R2	Operators	Industry, construction and services (except public administration, defence, compulsory social security)
	Technical/Engineering consultancy	Professional, scientific and technical activities
	Administrator	Public administration and defence; compulsory social security

Assumptions
25% Overhead
18.70% is a EU-27 average gross operating rate for architectural and engineering activities: technical testing and analysis sector in 2009
http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Sectoral_breakdown_of_key_indicators,_professional,_scientific_and_technical_activities_(NACE_Section_M),_EU-27,_2009_B.png&filetimestamp=20120524142710

Average hourly wage, non-wage labour cost and overhead (25%)		
	2012 prices	
Operators	**39**	€ per hour
Technical/Engineering consultancy	**48**	€ per hour
Administrator National CA	**41**	€ per hour
European Commission	**76**	€ per hour

Average hourly fee for external consultancy		
Technical/Engineering consultancy	**59**	€ per hour
if using 25%	**64**	€ per hour

Industry, construction and services

Weighted cost (2010) 36.97 € per hour

	% Total wages and salaries	% Social security and other labour costs paid by employer	Hourly Earnings	Non-Wage Labour Cost	Overhead	Total	Monthly Hours Paid
Unit	%	%	€/hour	€/hour	€/hour	€/hour	hours
European Union	78.37	21.65	26.15	7.22	8.34	41.72	167
Belgium	72.0	28.0	37.32	14.51	12.96	64.79	159
Bulgaria	83.9	16.1	4.81	0.92	1.43	7.17	168
Czech Republic	73.1	26.9	11.45	4.21	3.92	19.58	173
Denmark	87.1	12.9	42.45	6.29	12.18	60.92	157
Germany (includi	77.9	22.1	35.83	10.16	11.50	57.49	171
Estonia	:	:	9.74	2.69	3.11	15.54	169
Ireland	86.6	13.4	30.5	4.72	8.80	44.02	161
Greece	79.4	20.9	26.15	6.88	8.26	41.29	167
Spain	73.7	26.3	23.34	8.33	7.92	39.59	169
France	66.6	33.4	29.42	14.75	11.04	55.22	157
Italy	:	:	36.58	10.10	11.67	58.35	164
Cyprus	:	:	31.16	8.61	9.94	49.71	171
Latvia	79.1	20.9	6.5	1.72	2.05	10.27	167
Lithuania	72.2	27.8	5.94	2.29	2.06	10.28	167
Luxembourg	86.0	14.0	49.83	8.11	14.49	72.43	169
Hungary	74.4	25.6	9.95	3.42	3.34	16.72	170
Malta	91.1	8.9	14.17	1.38	3.89	19.44	179
Netherlands	:	:	28.05	7.75	8.95	44.75	164
Austria	73.8	26.2	33.41	11.86	11.32	56.59	173
Poland	:	:	10.08	2.78	3.22	16.08	163
Portugal	80.9	19.1	21.16	5.00	6.54	32.69	169
Romania	76.8	23.2	6.98	2.11	2.27	11.36	171
Slovenia	85.7	14.3	20.51	3.42	5.98	29.92	166
Slovakia	74.5	25.5	10.49	3.59	3.52	17.60	165
Finland	77.9	22.1	36.37	10.32	11.67	58.36	165
Sweden	67.1	32.9	27.75	13.61	10.34	51.70	173
United Kingdom	84.3	15.7	27.76	5.17	8.23	41.16	171

Professional, scientific and technical activities

Weighted cost (2010) 45.37 € per hour

	% Total wages and salaries	% Social security and other labour costs paid by employer	Hourly Earnings	Non-Wage Labour Cost	Overhead	Total	Hours Paid
Unit	%	%	€/hour	€/hour	€/hour	€/hour	hours
European Union	79.07	20.93	34.02	9.00	10.76	53.78	168
Belgium	72.0	28.0	41.58	16.17	14.44	72.19	162
Bulgaria	86.5	13.5	6.94	1.08	2.01	10.03	168
Czech Republic	73.7	26.3	15.1	5.39	5.12	25.61	172
Denmark	89.2	10.8	56.33	6.82	15.79	78.94	160
Germany (includi	81.5	18.5	46.17	10.48	14.16	70.81	172
Estonia	:	:	12.36	3.41	3.94	19.72	169
Ireland	86.0	14.0	34.94	5.69	10.16	50.78	163
Greece	78.2	21.8	34.02	9.48	10.88	54.38	168
Spain	75.3	24.7	23.7	7.77	7.87	39.34	174
France	66.9	33.1	31.46	15.57	11.76	58.78	170
Italy	:	:	43.99	12.15	14.04	70.18	165
Cyprus	:	:	30.71	8.48	9.80	48.99	168
Latvia	79.4	20.6	8.89	2.31	2.80	14.00	168
Lithuania	73.3	26.7	7.73	2.82	2.64	13.18	169
Luxembourg	85.5	14.5	64.83	10.99	18.96	94.78	171
Hungary	74.7	25.3	14.14	4.79	4.73	23.66	167
Malta	92	8.0	18.43	1.60	5.01	25.05	172
Netherlands	:	:	35.26	9.74	11.25	56.25	167
Austria	75.6	24.4	48.75	15.73	16.12	80.61	174
Poland	:	:	13.89	3.84	4.43	22.16	168
Portugal	78.5	21.5	26.02	7.13	8.29	41.43	169
Romania	77.4	22.6	10.69	3.12	3.45	17.26	168
Slovenia	86.9	13.1	21.03	3.17	6.05	30.25	166
Slovakia	75.8	24.2	12.66	4.04	4.18	20.88	165
Finland	79.8	20.2	39	9.87	12.22	61.09	162
Sweden	66.0	34.0	35.57	18.32	13.47	67.37	172
United Kingdom	85.4	14.6	40.18	6.87	11.76	58.81	164

Public administration and defence; compulsory social security

Weighted cost (2010) 38.67 € per hour

	% Total wages and salaries	% Social security and other labour costs paid by employer	Hourly Earnings	Non-Wage Labour Cost	Overhead	Total	Hours Paid
Unit	%	%	€/hour	€/hour	€/hour	€/hour	hours
European Union	79.09	20.91	18.29	4.83	5.78	28.91	165
Belgium	72.0	28.0	41.58	16.17	14.44	72.19	157.10
Bulgaria	79.3	20.7	3.31	0.86	1.04	5.22	168
Czech Republic	73.2	26.8	8.5	3.12	2.91	14.53	178
Denmark	90.1	9.9	42.18	4.63	11.70	58.52	159
Germany (includi	69.2	30.8	46.17	20.55	16.68	83.40	168.95
Estonia	:	:	11.05	3.05	3.53	17.63	169
Ireland	93.3	6.7	43.96	3.16	11.78	58.90	156
Greece	89.9	10.1	18.29	2.05	5.09	25.43	165
Spain	75.5	24.5	20.7	6.72	6.86	34.30	161
France	:	:	30.44	8.41	9.71	48.56	152
Italy	:	:	40.29	11.13	12.85	64.26	162.04
Cyprus	:	:	30.94	8.54	9.87	49.35	166
Latvia	79.1	20.9	7.38	1.95	2.33	11.66	168
Lithuania	74.6	25.4	6.88	2.34	2.31	11.53	168
Luxembourg	:	:	57.33	15.83	18.29	91.45	166.98
Hungary	74.1	25.9	10.34	3.61	3.49	17.44	168
Malta	82.9	17.1	16.30	3.36	4.92	24.58	176.86
Netherlands	:	:	28.86	7.97	9.21	46.04	158
Austria	:	:	41.08	11.35	13.11	65.53	170.93
Poland	:	:	8.96	2.47	2.86	14.29	168
Portugal	83.0	17.0	23.59	4.83	7.11	35.53	166.98
Romania	77.0	23.0	5.46	1.63	1.77	8.86	168
Slovenia	83.9	16.1	19.40	3.72	5.78	28.90	166
Slovakia	73.5	26.5	10.27	3.70	3.49	17.47	159
Finland	74.8	25.2	32	10.77	10.69	53.44	161
Sweden	:	:	30.88	8.53	9.85	49.26	174
United Kingdom	78.3	21.7	27.19	7.54	8.68	43.41	168

Non-BAU Measures - Qualitative Analysis

Item	Measures
1a	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
1b	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
2f	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells and other potential pathways for fluid migration, and other sensitive areas
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
9a	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
9b	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
13b i	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)
13c	Ownership and liability of wells transferred to a competent authority on surrender of the site licence following a period of monitoring
22c	Multiple barriers between the target formation and people/the environment, including minimum vertical distance between target formation and aquifers
26c	Fracturing to be a minimum distance from water resources
26g	Implementation of remedial measures if well failure occurs
27c	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
27f	Operators keep records of all waste management operations and make them available for inspection (e.g. of flowback, produced water management)
28d	Sharing of information to ensure that all operators in a gas play are aware of risks and can therefore plan
29a	Good practice construction / deconstruction practices, including design for well abandonment
30e	Muds restricted to approved list with known properties/safety data or, non-toxic drilling muds
33a	Good site practice to prevention of leaks and spills
36c	Treatment requirements for wastewater and capability of treatment works to treat wastewater established
38a	Notification of water demand from fracturing operations to relevant water utilities and competent authorities
38c	Water management plan
38e	Use of lower quality water for fracturing (e.g. non-potable ground / surface water, rainwater harvesting, saline aquifers, sea water, treated industrial waterwaters)
40a	Optimisation from an environmental perspective, i.e. the number of wells, pad density and pad spacing
40a	Optimisation from an environmental perspective, i.e. the number of wells, pad density and pad spacing
40b	Compatibility with current and future potential landuse (Natura 2000 sites, conservation sites, human use, industrial use, appropriate zoning, CCS, geothermal, water abstraction)
40c	High land, agricultural and ecological value locations avoided

Non-BAU Measures - Qualitative Analysis

Item	Measures
42b	Location of sites close to existing pipeline infrastructure
51a	Maximum noise levels specified
51d	Operational hours specified
51e	Vehicle routes specified
51f	Machinery orientation and selection to minimise noise
55e	Avoid high seismicity risk areas
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)
55h	Smaller preinjection prior to main operations to enable induced seismicity response to be assessed
55i	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers (e.g. 600m) and the surface (e.g. 600m depth requires special permit)
59c	Integration of road safety aspects into the traffic management plan
59d	Use of vehicles (water, chemicals, waste trucking) that meet minimum air emission standards e.g. EURO standards
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
61a	Use of temporary surface pipes for collection of produced water
61c	Site selection close to wastewater treatment / disposal facilities to minimise haulage requirements
N02	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
N03	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
N04	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
N05	Initiate immediate flowback post fracturing
N07	Operator to use alternative fracturing fluids to water (e.g. nitrogen, CO2, propane)
N08 a	In the case of an incident/accident significantly affecting the environment: (a) operator informs competent authority immediately
N08 b	In the case of an incident/accident significantly affecting the environment: (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
N10	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]
N11	Operator to provide financial guarantee to competent authority to cover costs of any remedial action following transfer of responsibility
N12	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)
N18	Ensure equipment is compatible with composition of fracturing chemicals
N19	Carry out thorough planning and testing of equipment prior to hydraulic fracturing operations
N21	Implement precautions to prevent invasive species by cleaning vehicles
N22	Maintain records of well location and depth indefinitely
N23	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
N25	Reversal of the burden of proof for unconventional gas operators in the context of liability in case of environmental damage
N28	Assessment by the Competent Authority of the technical and financial capacity of an operator
N29	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)
N32	Competent Authorities have available sufficient inspection capacity and appropriately skilled inspectors

Non-BAU Measures - Qualitative Analysis

Item	Measures
N33	Independent inspection during all stages of development of well integrity
N35	Member States implement integrated permitting for unconventional gas
N36	Operators work together to ensure efficient provision of gas collection and wastewater treatment infrastructure
N37	Pad construction activities staged to reduce soil erosion and to coincide with low rainfall periods
N38	Maintain operator liability for any pollution arising from wells for a period of 100 years
N39	Maintain operator liability for any pollution arising from wells indefinitely
N42	Prohibit non-disclosure agreements between local residents and/or landowners and unconventional gas operators
N44	Competent authorities compile regional maps of underground resources
N45	Members States establish a capability to address groundwater contamination arising from unconventional gas operations. In the case of transboundary aquifers, joint capability established
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
N47	Operator demonstrates availability of appropriate wastewater treatment facilities
N48	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers and the surface to be determined based on risk assessment
N49	Strategic planning and staged approach of play development to avoid peaks in water demand
N50	Lined open ponds with safety net protecting biodiversity
N51	Consider wastewaters hazardous unless operator demonstrates otherwise
N52	Ban injection of wastewaters into geological formations for disposal
N53	Consider wastewaters from unconventional gas operations as hazardous waste
N54	Encourage industry voluntary approach to reduce air pollutants and greenhouse gases
CAH1	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
CSL1a	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A or 1B
CSL2	Non-use of any substances on REACH Candidate List for authorisation (substances of very high concern)
CSL4	Demonstration that all steps practicable have been taken to reduce number, concentration and volume of chemicals used in hydraulic fracturing
CSL5	Authorities to organise an exchange of views/information on environmentally safer technologies and alternatives to the use of chemicals in hydraulic fracturing
CSM1a	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
CSM1b	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
CSM1c	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
CSM1d	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
CSM3	Selection of substances (chemicals and proppants) that minimise the need for treatment when present in flowback water
CSM4	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.
CSH1	Use of water or inert materials only in hydraulic fracturing
CSH2a	Non-use of any (non-biocidal) substances with [harmonised or notified] classification for any health or environmental effects
CSH2b	Non-use in biocidal products of any substances with [harmonised or notified] classification for any health or environmental effects
CDL1	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

Non-BAU Measures - Qualitative Analysis

Item	Measures
CDL2	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
CDM1	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
CDM2	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
CDH1	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

Measure Summary: 1a Prohibit operations within and underneath specified sites

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
1a	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	Applicable per pad and per play. Prohibit operations within specified sites (see measure description) or within certain distances to specified sites. Operations prohibited in the following locations: - within 1,000m of abstraction points and aquifers for drinking water - with 1,600m of residential areas, schools hospitals and other sensitive areas - areas with abandoned wells and other potential pathways for fluid migration (distance specified on risk basis) - water extraction areas for public drinking water supply - mineral spa protection zones and mineral water reserves - areas known to be unfavourable with regard to potential environmental impacts For details on distances and sources ref. to AMEC Measure Synthesis document.	Operators	Operations would be prohibited within specified areas. Pads and operations will need to be situated taking account of specified areas. Costs could be: - increased site identification costs - potential sunk costs due to prohibited sites being identified - potential lost revenue due to no access to gas reserves	Impacts (e.g. pollution of aquifers, nuisance to built up areas, noise nuisance) on sensitive sites will be prevented and/or mitigated. Damage potential in the event of an incident will be reduced. Greater potential benefit than 1b (restriction in/near specified sites)

Measure Summary: 1b Restrict operations within and underneath specified sites

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
1b	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	Applicable per pad and per play. Restrict operations within specified sites (see measure description) or within certain distances to specified sites. Distance restrictions would be: - require buffer zone from abstraction points and aquifers of 1,000m for drinking water related abstraction - require buffer zone from residential areas, schools hospitals and other sensitive areas of 1,600m - require buffer zone within which detailed noise assessment is required of 305m - require buffer zone from abandoned wells and other potential pathways for fluid migration (distance specified on risk basis) - require additional containment for sites near surface water supply locations (e.g. within 800m) For details on distances and sources ref. to AMEC Measure Synthesis document.	Operators	Operations would be restricted (i.e. greater controls as required by the MS authorities) within specified areas. Pads and operations will need to be situated taking account of sensitive areas. Costs could be: - increased site identification costs - potential sunk costs due to inappropriate sites initially being identified - potential lost revenue due to limiting access to gas reserves - increased costs for additional site containment	Impacts (e.g. pollution of aquifers, nuisance to built up areas, noise nuisance) on sensitive sites will be prevented and/or mitigated. Damage potential in the event of an incident will be reduced.

Measure Summary 2f Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells and other potential pathways for fluid migration, and other sensitive areas

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
2f	Buffer zones from abstraction points, aquifers, residential areas, schools, hospitals, abandoned wells and other potential pathways for fluid migration, and other sensitive areas	Applicable per pad and per play. Applicable regardless of area type (i.e. not limited to Natura 2000 site and other specified sites). Hence applicability is broader. Distances restrictions would be: - require buffer zone from abstraction points and aquifers of 1,000m for drinking water related abstraction - require buffer zone from residential areas, schools hospitals and other sensitive areas of 1,600m - require buffer zone within which detailed noise assessment is required of 305m - require buffer zone from abandoned wells and other potential pathways for fluid migration (distance specified on risk basis) - require additional containment for sites near surface water supply locations (e.g. 800m of near surface water supply locations in Colorado) For details on distances and sources ref. to AMEC Measure Synthesis document.	Operators	Operations would be restricted (i.e. greater controls as required by the MS authorities) in all area (i.e. not limited to specified areas). Pads and operations will need to be situated taking account of sensitive areas. Costs could be: - increased site identification costs - potential sunk costs due to inappropriate sites initially being identified - potential lost revenue due to limiting access to gas reserves - increased costs for additional site containment	Impacts (e.g. pollution of aquifers, nuisance to built up areas, noise nuisance) on sensitive sites will be prevented and/or mitigated. Damage potential in the event of an incident will be reduced. Greater potential benefit than 1b (restriction in/near specified sites only)

Measure summary: 7 Cumulative impacts

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
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	Applicable per pad and per play. Cumulative effects to be evaluated to understand impact and required mitigation measures: - assess cumulative impacts on local air quality due to point source releases from the pad and also vehicle movements - assess cumulative impacts of traffic on local traffic flows and transport infrastructure - assess cumulative impact of water resource depletion on groundwater and surface water resulting from water requirements - assess cumulative impact of landtake and the developments on noise, biodiversity and visual impact. Complimentary with other measures associated with planning.	Operators	Studies on the nature and mitigation of cumulative effects relevant to the specific site location will be required. Pads and operations may need to be situated in alternative locations to reduce effects. Operations may need to be scaled to avoid/mitigate unacceptable cumulative effects. Costs could be: - study costs as relevant/specific to the site - increased costs of site identification and development - potential sunk costs due to inappropriate sites initially being identified - potential lost revenue due to limiting access to gas reserves	Cumulative effects associated with unconventional gas development are avoided/mitigated (i.e. particularly those associated with landtake, visual impact, water resource depletion, traffic and local air quality). The cumulative effects of existing and other planned developments are integrated into the assessment.

Measure Summary: 9a Consideration of major hazards for all stages in the life cycle of the development

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
9a	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	Applicable per pad Identify and evaluate major hazards for the whole life of the development, including those that may be presented from other neighbouring operations. Revisit hazard assessment throughout the life of the development. Development of health, safety and environment case to demonstrate the effectiveness and adequacy of the pad, site facilities/infrastructure, well design and operational management measures put in place to prevent/mitigate major hazards.	Operators	A requirement to perform necessary pad-specific studies taking into account site specific hazards and also potential pathways and receptors. Consideration of adjacent hazards that may affect the site included. Repeat studies and audits of assessments. Adapting design and operational process and emergency response process as necessary in line with study findings. Adaptation of site location due to the need to avoid extant (offsite) hazards. Costs could be: - studies (as above) - repeat studies and audits - necessary adaptation of site/well design	Prevention/ avoidance of major hazards that could result in events that could result in significant environmental or safety impacts (e.g. major spills of chemicals, fuel or wastes)

Measure Summary: 9b Emergency response plan developed and put in place

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
9b	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	Applicable per pad Identify and evaluate potential incidents that could result in an emergency across the whole life of the development and development of emergency response plans to manage events. Revisit the assessment throughout the life of the development. Development of emergency response approaches to the identified potential emergencies (particularly 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.	Operators	A requirement to perform necessary pad-specific studies taking into account site specific infrastructure, facilities and operations and also potential pathways and receptors. Repeat studies and audits of the appropriateness of the plans. Adapting design and operational process to enable effective emergency responses as necessary in line with study findings. Costs could be: - studies (as above) - repeat studies and audits - necessary adaptation of site/well design and operational practices	Mitigation of potential polluting events resulting from emergencies, e.g. mitigation of groundwater and surface water pollution, mitigation/control of events from the release of flammable gas, control of fire and flood events and control of leaks and spillages.

Measure Summary: 13b Specific post closure well inspection, maintenance and monitoring/reporting programme

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
13b i	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)	Applicable per well 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	Operator Competent authority	Operator: the operator would implement a monitoring and reporting programme for the wells and their surrounding areas after well closure in the event of pollution incident. Costs could be: - associated with monitoring tests and report preparation and submission. In the event that environmental damage is detected, operators would implement appropriate remediation measures. Competent authority: the CA will need to review monitoring and maintenance reports submitted by operators. Costs could be: - associated with reviewing and confirming the monitoring and maintenance reports.	Prevention of pollution arising from permanently abandoned wells
13b ii	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)	Applicable per well 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	Operator Competent authority	Operator: the operator would implement a monitoring and reporting programme for the wells and their surrounding areas after well closure in the event of pollution incident. Costs could be: - associated with monitoring tests and report preparation and submission. In the event that environmental damage is detected, operators would implement appropriate remediation measures. Competent authority: the CA will need to review monitoring and maintenance reports submitted by operators. Costs could be: - associated with reviewing and confirming the monitoring and maintenance reports.	Prevention of pollution arising from permanently abandoned wells

Measure Summary 13c Ownership and liability of wells transferred to a competent authority on surrender of the site licence following a period of monitoring

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
13c	Ownership and liability of wells transferred to a competent authority on surrender of the site licence following a period of monitoring	Applicable per pad. Following a period of monitoring 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 well.	Operator Competent authority	Operator: following a period of monitoring and site reinstatement, the operator would need to demonstrate that wells presented negligible/no future risk to the environment. Costs could be: - associated with demonstrating the case for transfer and administration of the transfer. Competent authority: the CA will need to be satisfied that wells presented negligible/no future risk to the environment. The CA will take on responsibility for the wells; no further monitoring or management will be necessary. In the event that environmental damage does occur, the CA will be responsible for assessment and remediation. Costs could be: - associated with reviewing and confirming the case for transfer and administration of the transfer.	Clear transfer of responsibilities and liability linked to the wells following closure and reinstatement. Transferring ownership and liability to a competent authority on surrender ensures that explicit tenure and legal responsibility is maintained regarding environmental risk management following relinquishment by the operator

Measure Summary 22c Multiple barriers between the target formation and people/the environment, including minimum vertical distance between target formation and aquifers

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
22c	Multiple barriers between the target formation and people/the environment, including minimum vertical distance between target formation and aquifers	Applicable per pad and per play. Complimentary with 26c and 55i. To avoid the unintentional penetration of rock strata that may provide a pathway to aquifers or subsurface geological storage sites, it is important to constrain the extent of hydraulic fracture distance. Davies et al. (2012) suggests the estimating hydraulic fracturing height based on mathematical methods supplemented with *in situ* data (i.e. microseismic measurement of fracture propagation) as the basis to set the minimum vertical separation between the shale gas reservoir and shallower aquifers.	Operators	Maintaining barriers would reduce the amount of reserves and areas available for development. It is difficult to estimate what proportion of the available reserves in the EU-27 would be affected by implementing this measure, due to lack of information. Costs could be: - assessment of the presence of suitable geological barriers and control of fracture distance on a site by site basis - potential lost revenue if suitable barriers are not present for a site resulting in constrained fracturing operations and reduced yields	This measure would reduce the potential risks of unintentional pollutant pathway creation and/or penetration of aquifers and subsequent pollution of the groundwater.

Measure Summary 26c Fracturing to be a minimum distance from water resources

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
26c	Fracturing to be a minimum distance from water resources	Applicable per pad and per play. Complimentary with 22c. Sites are located a minimum specified distance (horizontal) from groundwater resources to avoid/prevent unintentional pollution of aquifers.	Operators	Operations would not be permitted within specified distances of water resource (groundwater). Pads and operations will need to be situated taking account of specified groundwater resource areas. Costs could be: - increased site identification sites - potential sunk costs due to prohibited sites being identified - potential lost revenue due to no access to gas reserves	Assurance of risk reduction regarding possible transference contaminants in fluid to aquifers (and linked surface waters) via induced fractures extending beyond target formation (e.g. through bio-geological reactions with chemical additives, via pre-existing fractures/faults, via pre-existing man-made structures, well casing failure).

Measure Summary 26g Implementation of remedial measures if well failure occurs

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
26g	Implementation of remedial measures if well failure occurs	Applicable per well. In addition to those measures aimed to provide well integrity before, during and after the shale gas development, remedial measures would be required in the event of well failure and before the well is abandoned. Inspections should be carried out to identify if there are sections of the well that do not meet the specifications to trigger implementation of remedial measures. In addition, follow-up inspections should confirm that operators have remediated any defective well cementation effectively. For abandoned wells, any ineffective abandonment operations would be remediated.	Operators	Operators would need to plan and budget for remedial actions. Cost could be: - well reconstruction/repair - well abandonment (implementing required abandonment process) and closure - lost operational time and production	This measure will reduce environmental risks associated with well failure or improper well abandonment, i.e. pollution of groundwater and associated surface water.

Measure Summary 27c Injection of flowback and produced water into designated formations for disposal, provided specific conditions are in place:i) treated waste water andii) untreated wastewater

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
27c	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	Applicable per pad or play Deep injection of flowback and produced water is currently not permitted due to WFD restrictions. This measure will require a derogation similar to that for CO2 injected under CCS. The measure will require comparable predevelopment, operational and post closure/abandonment measures to the CCS Directive and to those being considered for UG developments. This may require: - baseline setting across a wide range of parameters - development of conceptual geological/hydrogeological model - modelling of potential induced seismicity and assessment of potential induced seismicity impacts - environmental risk assessment - establishment of potential long-term impacts on groundwater resources - SEA/EIA of injection plans/projects - ongoing monitoring across a range of parameters - establishment of permitting requirements - public consultation and disclosure of information - site closure and abandonment requirements - and so on These requirements for both treated and untreated wasterwater	European Institutions Competent authorities Operators	European Institutions - will need to consider adequacy of the current acquis. Costs could be: - staff time to assess - costs of technical support - engagement and consultation Competent authorities - will need to administer the permitting of facilities Costs could be: - staff time to develop permitting system and administer permitting - costs of technical support - engagement and consultation Operators will - need to carry out the required mitigation measures Costs could be: - extensive development costs (see measure detail for tasks)	Costs of treatment of flowback and produced water to the required discharge standard and subsequent discharge to surface waters will be avoided in i) Potential for pollution event to surface water and near surface groundwater resources is reduced

Measure Summary 27f Operators keep records of all waste management operations and make them available for inspection (e.g. of flowback, produced water management)

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
27f	Operators keep records of all waste management operations and make them available for inspection (e.g. of flowback, produced water management)	Applicable per well Accounting and tracking of flowback and produced water to assess proportion of fracturing fluid returned as flowback and to assure audit trail of wastewater management and treatment. Off the shale gas development site, accounting/tracking of waste is a business-as-usual practice under the WSR/WFD; however, these Directives do not prescribe the measure to be practiced on-site. This measure would extend the water/water accounting and tracking to include flowback and produced water from the shale gas development site.	Operators	Operators would need to estimate how much flowback and produced water will be generated and monitor actual amounts. Also for how it is transported and treated (either on-site and off-site). Costs could be: - setting up and maintaining a system for monitoring, tracking and auditing wastewater generation, transportation and treatment	By enhancing the knowledge of how much flowback and produced water is generated, handled and treated, it would allow the operators to better manage the wastewater from the site (and thus reducing the likelihood of pollution from the wastewater mis-management) and ensure all wastewater is accounted for.

Measure Summary 28d Sharing of information to ensure that all operators in a gas play are aware of risks and can therefore plan

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
28d	Sharing of information to ensure that all operators in a gas play are aware of risks and can therefore plan	Applicable per play This measure intends to increase the level of awareness of operators for issues presented by a given gas play regarding the potential risks that can lead to subsurface blowout events and the prevention strategies/methods that are appropriate. Sharing information on the risks and a plan of action will help operators understand better the potential risks and hence help develop risk mitigation approaches and thus minimise the risks of environmental pollution.	Operators	Operators would need to establish an open communication approach and share data and experiences, particularly on the risks that can lead to a blowout events and what to do in case of such an event at a given gas play. Operators would also need to update and remind its employees on these issues throughout the shale gas development stages. Costs could be: - time required to liaise with other operators and share data/experiences - time required to brief employees and adjust operating practices as necessary	Reduction in the risk of blowout events from taking place as well as to enhance the operators' ability to respond effectively to blowout events.

Measure Summary 29a Good practice construction / deconstruction practices, including design for well abandonment

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
29a	Good practice construction / deconstruction practices, including design for well abandonment	Applicable per pad This measure is focussed firstly on good practice construction and deconstruction techniques and secondly on required practices for well abandonment (refer to measures under 12 and 13 for well abandonment). Operators should apply construction industry good practice to prevent pollution of surface water through operator training and approach to construction practice.	Operators	Operators would be required to apply industry good practice to pad construction and deconstruction (and well abandonment - see measures 12 and 13). Cost could be: - assessment of site surface water pollution risks linked to construction and deconstruction - training of construction/demolition staff - introduction of required management practices to prevent/control spills and runoff during construction/deconstruction - provision of equipment to prevent/control spills and runoff during construction/deconstruction of pads	Pads constructed and deconstructed with minimised risk of pollution to surface water using industry good practice.

Measure Summary 30e Muds restricted to approved list with known properties/safety data or, non-toxic drilling muds

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
30e	Muds restricted to approved list with known properties/safety data or, non-toxic drilling muds	Applicable per well Specify the use of water-based muds and the use of non-toxic chemical additives that are from an approved list to minimise the risk of harmful (polluting) mud production which could result in polluting spills if not controlled and contained correctly.	Operators Members States	Operators to identify proposed drilling mud chemical additives. Member State competent authorities to approve chemicals for use. Operators to only use chemical additives approved by MS CAs. Costs would be: - cost of assessment of proposed chemical additives (by MS) - any additional cost incurred for the use of non-toxic/approved chemical additives (by operators)	This would allow MS government to restrict unwanted chemical substances to be used in drilling mud. Spillage of drilling mud would present a reduce hazard to the environment from chemical additives.

Measure Summary 33a Good site practice to prevention of leaks and spills

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
33a	Good site practice to prevention of leaks and spills	Applicable per pad Relevant to surface water pollution risks from chemical transportation, storage, mixing and use and also management of other liquids (wastewaters) and fuels. To complement technical measures, employees implement good site operational practices and are appropriately trained to prevent leaks and spills.	Operators	Employees would need to be appropriately trained and aware of site good practice when managing chemicals (and wastewaters and fuels). Costs could be: - training and awareness programme for employees regarding required good site practice	Reduce risk of surface water pollution stemming from poor operator skills.

Measure Summary 36c Treatment requirements for wastewater and capability of treatment works to treat wastewater established

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
36c	Treatment requirements for wastewater and capability of treatment works to treat wastewater established	Applicable per pad. To ensure appropriate treatment of wastewater, the operator characterises the wastewater. The necessary treatment requirements can then be established. These may include treatment of NORM, salinity, grease/oil, metals. The necessary treatment requirements to address the contaminants can hence be determined/checked.	Operator	The operator would need to characterise wastewaters and determine, in conjunction with wastewater treatment service providers, the required treatment and/or suitability of treatment plant to properly treat wastewater to the relevant discharge limits. Costs could be: - characterisation of wastewater and discussion with wastewater treatment service providers on the required treatment and/or suitability of treatment available. Identification of the facilities capable of treating the wastewater, additional fees for treatment, transportation, etc.	Prevention of improperly treated flowback or produced water leading to pollution of surface water.

Measure Summary 38a Notification of water demand from fracturing operations to relevant water utilities and competent authorities

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
38a	Notification of water demand from fracturing operations to relevant water utilities and competent authorities	Applicable per pad (and possible per group of pads or per play) Inform relevant authorities (i.e. water utilities, environmental regulators, planning authorities) of water demand for the lifetime of the project.	Operators	An understanding of the water demand and planned sources will be required form the operator. The operator would be required to submit and discuss planned water demand needs with relevant authorities. Costs could be: - Operator to produce demand profile for development of well field (measure 38b) - Require water management plan (measure 38c) - resources to discuss plans and needs with authorities	Assurance that cumulative effects of demand from both fracturing operations and other unrelated current and planned operations/developments can be considered by the relevant authorities to avoid environmental pollution risks and water scarcity (see summary of potential impacts below). Potential impacts: water extraction can result in lowering the water table; dewatering aquifers and change in water quality (e.g. chemical contamination from mineral exposure to aerobic environment; bacterial growth due to lower water table; release of biogenic methane into superficial aquifers; upwelling of lower quality water or substances into aquifer; subsidence and destabilisation of geology. There is a potential cumulative effect of large numbers of operations, particularly in drought and dry periods but also in wet regions where there are stresses within existing water supplies due to substantial demands or limited infrastructure).

Measure Summary 38c Water management plan

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
38c	Water management plan	Applicable per pad (and possible per group of pads or per play) Develop a water and wastewater management plan to cover water supply and efficient use on site (e.g. recycling of flowback). Complimentary measures are 38a, 38b, 38d, 38e.	Operator	Assessment of site/play specific availability of water and demand profile. Assessment of flowback characteristics and suitability/potential for recycling into fracturing fluid. Costs could be: - costs of site/play specific studies - assessment and testing of suitability of flowback for recycling	Potential for reduced and/or optimum water deamnd and flowback recycling resulting in reduced pressure on water resources and hence reduced risk of related environmental pollution (see below for summary of potential impacts). Reduction in associated traffic movements linked to water supply and flowback management and associated emissions to air and noise. Potential impacts: water extraction can result in lowering the water table; dewatering aquifers and change in water quality (e.g. chemical contamination from mineral exposure to aerobic environment; bacterial growth due to lower water table; release of biogenic methane into superficial aquifers; upwelling of lower quality water or substances into aquifer; subsidence and destabilisation of geology. There is a potential cumulative effect of large numbers of operations, particularly in drought and dry periods but also in wet regions where there are stresses within existing water supplies due to substantial demands or limited infrastructure).

Measure Summary 38e Use of lower quality water for fracturing (e.g. non-potable ground / surface water, rainwater harvesting, saline aquifers, sea water, treated industrial waterwaters)

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
38e	Use of lower quality water for fracturing (e.g. non-potable ground / surface water, rainwater harvesting, saline aquifers, sea water, treated industrial waterwaters)	Applicable per well or pad Lower quality water, i.e. non-potable ground/surface water or harvested rainwater, is required for use to make up fracture fluid.	Operator	Sources of licensed non-potable water would need to be located. The suitability of the water for use in fracture fluid would need to be assessed. Cost could be: - sourcing of non-potable water - test to assure that water is suitable for use Savings could be: - reduced water supply costs due to lower quality requirement. During construction of the London Olympic games, an additional water abstraction borehole was made to enable non potable groundwater to be used. This resulted in a cost differential of £0.24 per m3 compared to £1.13m3. The amount of water required to offset the cost of the borehole was 225,000m3 (which was exceeded). Source: http://learninglegacy.independent.gov.uk/documents/pdfs/sustainability/158-non-potable-water-supply-sust.pdf Given the nature of operations, it is possible that lower quality water will be delivered by truck, the cost depends on the distance travelled/volumes needed at any one time and will have associated storange costs, which are quantified elsewhere.	Pressure on potable water sources is reduced.

Measure Summary 40a Optimisation from an environmental perspective, i.e. the number of wells, pad density and pad spacing

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
40a	Optimisation from an environmental perspective, i.e. the number of wells, pad density and pad spacing	Applicable per play. 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 adequately implemented by Member States.	Operator	Operations may not be optimal in certain areas. Pads and operations will need to be situated to take account of sensitive areas and receptors. Costs could be: - increased site identification costs - potential sunk costs due to inappropriate sites being identified initially - potential lost revenue due to limiting access to gas reserves	Assurance that site location is in the optimal location to minimise environmental impacts in broad terms taking account of cumulative effects, sensitive areas and receptors.

Measure Summary 40b Compatibility with current and future potential landuse (Natura 2000 sites, conservation sites, human use, industrial use, appropriate zoning, CCS, geothermal, water abstraction)

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
40b	Compatibility with current and future potential landuse (Natura 2000 sites, conservation sites, human use, industrial use, appropriate zoning, CCS, geothermal, water abstraction)	Applicable per play. Require compatibility with current and future potential landuse (Natura 2000 sites, conservation sites, human use, industrial use, appropriate zoning, CCS, geothermal, water abstraction) 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 excepted.	Operators Competent authorities	Consideration of pad location and associated environmental impacts in conjunction with current and future landuse plans in place. Liaison with relevant competent authorities to carry out the assessment. Costs could be (operators): - increased site assessment/identification costs - potential sunk costs due to inappropriate sites being identified initially - potential lost revenue due to limiting access to gas reserves Costs could be (competent authorities): - liaison costs with operators	Plans for current and future landuse are considered and hence the appropriate location of developments is achieved resulting in reduced potential for adverse cumulative impacts with other planned developments.

Measure Summary 40c High land, agricultural and ecological value locations avoided

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
40c	High land, agricultural and ecological value locations avoided	Applicable per play. Assessment of and avoidance of high land, agricultural and ecological value locations (e.g. Natura 2000 sites, conservation sites). Note: the *acquis communautaire* requires this measure, but it is uncertain whether it is adequately implemented by Member States.	Operators	Consideration of pad location and associated environmental impacts on high value locations Costs could be: - increased site assessment/identification costs - potential sunk costs due to inappropriate sites being identified initially - potential lost revenue due to limiting access to gas reserves	Appropriate location of developments is achieved resulting in reduced potential for adverse impacts with high value uses.

Measure Summary 42b Location of sites close to existing pipeline infrastructure

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
42b	Location of sites close to existing pipeline infrastructure	Applicable per play. Site selection takes into consideration existing gas pipeline infrastructure to enable minimisation of the need for additional pipeline infrastucture and associated development impacts. Note: the *acquis communautaire* requires this measure, notably as mitigation measure under the SEAD/the EIAD, but without guarantee of the result.	Operators	Consideration of pad location in conjunction with existing pipeline infrastucture. Costs could be (operators): - increased site assessment/identification costs - potential sunk costs due to inappropriate sites being identified initially	Minimisation of impacts associated with new pipeline infrastructure development (e.g. excavation, construction, vehicle movements, disturbance of ecology).

Measure Summary 51a Maximum noise levels specified

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
51a	Maximum noise levels specified	Applicable per pad. Competent authorities in MSs specify maximum noise levels permissible from the site. Operators comply with site specific maximum noise levels through operational controls or installation of necessary noise mitigation equipment (screens, cladding, etc.)	Operators Competent authorities	To comply, operators may need to provide noise mitigation on plant. Site and plant specific. Competent authorities would need to assess the required maximum noise levels taking account of receptors and impacts. Costs could be (operators): - installation of any required noise mitigation to meet specified levels Costs could be (competent authorities): - assessment of site specific maximum noise levels required	Noise nuisance impact from site operations on residents and wildlife is reduced to acceptable/required level.

Measure Summary 51d Operational hours specified

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
51d	Operational hours specified	Applicable per pad. Competent authorities in MSs specify operational hours to mitigate noise impacts on sensitive receptors. Operators comply with site specified operational hours.	Operators Competent authorities	To comply, operators will need to limit/adjust operating hours to the specified times. Competent authorities would need to assess the required operating hours taking account of receptors and impacts. Costs could be (operators): - reduced/limited hours of operation may impact on productivity Costs could be (competent authorities): - assessment of site specific requirements	Noise nuisance impact from site operations on residents and wildlife is reduced to acceptable/required level.

Measure Summary 51e Vehicle routes specified

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
51e	Vehicle routes specified	Applicable per pad or group of pads Vehicle routes are specified to ensure noise nuisance is mitigated to sensitive receptors (wildlife, residents) from trucks (e.g. those transporting construction materials, water, chemicals, site equipment, wastewater). Operators comply with site specific routes.	Operators	Assessment of available routes would be required to establish optimal routes to avoid noise nuisance to sensitive receptors. Design of specific vehicle routes to minimise impacts. Cost could be: - assessment of optimum routes - potential increase in transport costs if routes increase haulage distances	Noise nuisance impact from traffic on residents and wildlife is reduced to acceptable/required level.

Measure Summary 51f Machinery orientation and selection to minimise noise

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
51f	Machinery orientation and selection to minimise noise	Applicable per pad. Operators select machinery and orientate machinery on site to minimise noise to receptors. Highly site specific.	Operators	Selection of machinery and its orientation on site to minimise noise to receptors. Costs could be: - selection of reduced noise equipment (if available) - adjustment of site layout to reduce noise to receptors - reduced flexibility of site layout reducing productive use of site	Noise nuisance impact from site operations on residents and wildlife is reduced to acceptable/required level.

Measure Summary 55e Avoid high seismicity risk areas

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
55e	Avoid high seismicity risk areas	Applicable per pad. Areas with the potential for triggering seismic events and/or the potential for significant responses to induced seismicity are identified. Where necessary, such areas are avoided for fracturing operations to minimise the risk of impacts resulting from triggering seismic response to induced seismicity (e.g. activation of faults creating pollutants pathways and deformation of wells). Following initial desk study work and assessment of information, identify areas with high seismicity risk potential and avoid such locations for operations.	Operators	Operations would not be possible in high seismicity risk areas. Pads and operations will need to be situated taking account of specified areas. Desk study required as part of exploration and establishing the baseline for seismicity (see measure 3a) and high seismicity risk areas are identified. Operations in high risk areas would be avoided. Cost could be: - increased cost of site identification - potential sunk costs due to inappropriate sites initially being identified - potential lost revenue due to limiting access to gas reserves	Assurance that high seismicity risk areas are avoided and hence linked risks are minimised/prevented (e.g. fault activation and pathway creation, well deformation leading to pollution events from the well to groundwater)

Measure Summary 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)

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
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)	Applicable per pad and play Engagement with third parties such as other operators, mining and oil and gas drilling companies, water companies, research institutes and geological survey organisations to establish full details of underground activities (e.g. other wells, mines, shafts, underground storage facilities) that may be affected or may affect planned operations This measure intends to increase the level of awareness of operators of existing/planned underground activities that could be affected by induced seismicity . A better understanding of the potential receptors (of induced seismicity) can be developed and hence operational plans can be developed taking account of necessary risk mitigation and thus minimise the risks of environmental pollution. Engagement would be with other oil & gas operators, competent authorities, mining and waste companies and water companies.	Operators	Operators would need to carry out engagement with relevant third parties to gather information. Assessment of information and identification of issues/proximity of areas with existing underground structures/uses that could be affected by induced seismicity. Assessment of risks presented and development of plans to mitigate risks. Costs could be: - time required to liaise with third parties, assess information and adjust plans to mitigate risks - increased cost of site identification - potential lost revenue due to limiting access to gas reserves	Identification of possible underground structures and pollutant pathways that need to be considered in the planning of operations and consequently consideration of such information in the mitigation of environmental pollution, particularly to groundwater and surface water. Mitigation of the risk of damage to third party existing underground structures and associated pollution and/or loss of third party income (that could result in claims).

Measure Summary 55h Smaller preinjection prior to main operations to enable induced seismicity response to be assessed

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
55h	Smaller preinjection prior to main operations to enable induced seismicity response to be assessed	Applicable per well 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.	Operators	Small-scale preinjection tests and monitoring of the seismicity response will be required. If a significant (e.g. unexpected or large scale) response is found from the tests, re-evaluation of the site or nature of operations may be required if it is suggested that induced seismicity from full-scale fracturing could result in environmental pollution (e.g. through activation of faults and rock fractures that facilitate pollution of overlying aquifers). Cost could be: - cost of the mini-frac - delays to moving to full scale production - abandonment of well and/or site due to a significant risk of pollution - potential sunk costs due to unsuitable sites being abandoned - potential lost revenue due to no or limited access to gas reserves	Conceptual and fracturing model predictions can be checked and verified resulting in greater assurance regarding the avoidance of groundwater and surface water pollution due to aspects such as activation of faults and geological fractures that may result in pollutant pathways. Avoidance and/or better control of operations at unsuitable sites resulting in reduced pollution risk. Assurance that unsuitable sites are avoided. Assurance that modelled geological response to induced seismicity is correct. Ability to adjust full-scale operations to account for the site specific response and hence avoid impacts associated with adverse reaction to induced seismicity (e.g. fault activation leading to pollutant pathway creation and/or well deformation leading to pollution event).

Measure Summary 55i Minimum distance between hydraulic fracture pipes and geological strata containing aquifers (e.g. 600m) and the surface (e.g. 600m depth requires special permit)

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
55i	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers (e.g. 600m) and the surface (e.g. 600m depth requires special permit)	See 22c Applicable per well. Fractures may extend a few hundred metres from the well (re. Royal Society 2012). To minimise the risk of fractures extending into aquifers, a minimum distance of 600m should be established between the well and any aquifer and/or the surface. Assessment of aquifer is required to establish the minimum well depth. If wells are proposed <600m from aquifers or the surface, then special conditions may be required in permits (e.g. monitoring and assessment of fracture length and monitoring of the aquifer for pollution by gas, salinity, metals and NORM).	See 22c Operators	See 22c Need to establish aquifer depth and map against well depth. Need to monitor fracture length. If well is within 600m of the aquifer, then additional aquifer monitoring will be required. Cost could be: - Assessment of aquifer depth - Increased monitoring and control of well drilling and fracturing operations to monitor fracture length - Potential additional monitoring costs if well is within 600m of an aquifer	See 22c Avoidance of fractures extending near to or into aquifers and hence avoidance of groundwater and/or surface water pollution potential.

Measure Summary 59c Integration of road safety aspects into the traffic management plan

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
59c	Integration of road safety aspects into the traffic management plan	Applicable per pad. Complementary with 59b (Require transport management plan). Consider road safety as part of the plan identifying impacts on road safety, road safety risks and mitigation measures as part of the plan.	Operators	Requirement to consider impacts on road safety in the transport management plan alongside logistical aspects. Cost could be: - Additional road safety assessments and development of mitigation measures	Assurance that potential impacts on road safety resulting from vehicle movements associated with the site (e.g. for construction, plant movement, water and waste water haulage) are addressed.

Measure Summary 59d Use of vehicles (water, chemicals, waste trucking) that meet minimum air emission standards e.g. EURO standards

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
59d	Use of vehicles (water, chemicals, waste trucking) that meet minimum air emission standards e.g. EURO standards	Applicable per pad or play Vehicles that meet minimum standards (e.g. EURO standards) are specified for use on the site and for haulage associated with the site (e.g. during construction, delivery of plant and haulage of materials, chemicals, water and wastewater).	Operators	Require all own vehicles and those of contractors and haulage contractors to meet minimum air emission standards. Cost could be: - replacement of non-compliant vehicles by operator - increased cost to operator in subcontracts reflecting premium for higher standard vehicles	Assurance that vehicle emissions (release to air) are minimised through the use of compliant vehicles.

Measure Summary 60a Use of temporary surface pipes for distribution of water supply

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
60a	Use of temporary surface pipes for distribution of water supply	Applicable per group of pads or play. Temporary pipes are laid above ground to supply water to pads. Following completion of fracturing, pipes are removed - potentially being transferred to a different location for reuse. Measure is dependant on a number of aspects including cost effectiveness, land availability to lay surface pipes and permission to lay pipes.	Operators Water supply companies	Installation of piping and pumping infrastructure and it maintenance. Obtaining of access rights to lay pipes. Removal of pipes following use. Cost could be: - Cost of installing water pipes and associated pumping infrastructure and the maintenance and operation of the system Savings could be: - reduced water haulage costs	Reduction in impacts stemming from traffic associated with water haulage and linked environmental impacts of air pollution, noise/vibration, visual, community severance, accidents, spillage risk.

Measure Summary 60b Use of temporary surface pipes for collection of flowback

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
60b	Use of temporary surface pipes for collection of flowback	Applicable per group of pads or play. Temporary pipes are laid above ground to collect flowback and transport to treatment plant. Pipes remain in place for transport of produced water. Following ceasing of operations, pipes are removed - potentially being transferred to a different location for reuse. Measure is dependant on a number of aspects including cost effectiveness, land availability to lay surface pipes and permission to lay pipes.	Operators Wastewater treatment utilities	Installation of piping and pumping infrastructure and it maintenance. Obtaining of access rights to lay pipes. Removal of pipes following use. Cost could be: - Cost of installing pipes and associated pumping infrastructure and the maintenance and operation of the system Savings could be: - reduced flowback haulage costs	Reduction in impacts stemming from traffic associated with flowback haulage and linked environmental impacts of air pollution, noise/vibration, visual, community severance, accidents, spillage risk.

Measure Summary 60c Site selection close to water sources to minimise haulage requirements

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
60c	Site selection close to water sources to minimise haulage requirements	Applicable per pad or play Consideration of the proximity of water sources as part of the site selection process to enable haulage distances to be minimised. Will first require water sources to be determined.	Operators	Identification of water sources and pad location options. Inclusion of proximityy to water sources as part of site selection where options are available. Cost could be: - additional (minor) costs in site selection process	Reduction in impacts stemming from traffic associated with water haulage and linked environmental impacts of air pollution, noise/vibration, visual, community severance, accidents, spillage risk.

Measure Summary 61a Use of temporary surface pipes for collection of produced water

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
61a	Use of temporary surface pipes for collection of produced water	Applicable per group of pads or play. Temporary pipes are laid above ground to collect produced water and transport to treatment plant. Pipes may have remained in place from collection and transport of flowback. Following ceasing of operations, pipes are removed - potentially being transferred to a different location for reuse. Measure is dependant on a number of aspects including cost effectiveness, land availability to lay surface pipes and permission to lay pipes.	Operators Wastewater treatment utilities	Installation of piping and pumping infrastructure and it maintenance. Obtaining of access rights to lay pipes. Removal of pipes following use. Cost could be: - Cost of installing pipes and associated pumping infrastructure and the maintenance and operation of the system Savings could be: - reduced produced water haulage costs	Reduction in impacts stemming from traffic associated with flowback haulage and linked environmental impacts of air pollution, noise/vibration, visual, community severance, accidents, spillage risk.

Measure Summary 61c Site selection close to wastewater treatment / disposal facilities to minimise haulage requirements

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
61c	Site selection close to wastewater treatment / disposal facilities to minimise haulage requirements	Applicable per pad or play Consideration of the proximity of wastewater treatment plant as part of the site selection process to enable haulage distances to be minimised.	Operators	Identification of wastewater treatment plant and pad location options. Inclusion of proximity to wastewater treatment plant as part of site selection where options are available. Cost could be: - additional costs in site selection process	Reduction in impacts stemming from traffic associated with water haulage and linked environmental impacts of air pollution, noise/vibration, visual, community severance, accidents, spillage risk.

Measure summary: N02 Independent evaluation of environmental risk management measures

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N02	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	Applicable per pad or concession External assessment of risk management measures and ongoing monitoring of the efficacy of the measures in place.	Operator	In practice the requirements are likely to be similar to Quality Management System (QMS) accreditation and auditing requirements and/or the 'environmental statement' considering risks and their mitigation that is required as part of submission for EMS accreditation. Measure is listed as a qualitative measure, but costs are available and depend on company turnover. Costs could be (based on similar to QMS UK costs 2013). There are broad QMS Categories (A and B which indicate differing standards/requirements . B is the higher standard. Fees for QMS accreditation from £2,374 Category A, and £5,249 for Category B. Fees for audit are £795 (assumed audit is an annual cost). Fees assume operator turnover would be at least £5-10 million. Source: http://www.qmsuk.com/qms-fees-and-offers.php	Independent assessment of risk posed by operation, ongoing audit to ensure compliance and adherence to permit conditions. Potential to mitigate and/or avoid environmental accidents.

Measure Summary: N03 Permits/authorisations/licences relating to environmental risk management made available to the public

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N03	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	Applicable per pad or play As with N04, access to information for the public will be important to increase understanding of issues and help encourage informed and objective discussion based on the correct key issues. The storing of all permit/authorisations/licences relating to environmental risk management will contribute to this aim. It will also enable required practices and permit conditions to be compared across MSs, aiding coherant approaches to regulation. The permits/authorisations would include SEA, EIA, operating permits, closure and post closure documents including applications and decision documents. The documents will be catalogued on a central data repository for all shale gas operations in the Member State / EU and be available for inspection by the public.	EU institutions MS regulatory insitutions Operators	EU/MS institions would be required to collate and catalogue the information. Costs could be: - collection of information and maintenance of a data repostary - responding to requests for information from the public Operators: No costs as documents submitted to authorities.	Increased access to information to increase understanding of issues and help encourage informed and objective discussion based on the correct key issues. Ability to compare the required practices and permit conditions across MSs, aiding coherent approaches to regulation. Increased potential for public scrutiny that may result in increased and more extensive considerations of issues of concern to the public.

Measure Summary: N04 EU institutions and/or Member States provide peer reviewed information to the public

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N04	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	General applicability. As with N03, access to information for the public will be important to increase understanding of issues and help encourage informed and objective discussion based on the correct key issues. The provision of information regarding current knowledge of environmental risks and mitigation measures will assist in this. The latest research and information regarding risks and mitigation measures would be made available (e.g. through a website) centrally by EU institutions and/or at the MS level.	EU and/or MS institutions/authorities Operators and the public	EU and/or MS institutions/authorities Establishment and maintenance of a website holding information on current knowledge of environmental risks and mitigation measures. Costs would be: - website establishment and maintenance - collation of research and emerging information Operators and the public have increased access to latest/emerging information	Increased access to emerging information on environmental risks and mitigation measures for all stakeholders. Ability to compare proposed practices with emerging measures. Increased potential for public scrutiny that may result in increased and more extensive considerations of emerging measures.

Measure Summary N05 Initiate immediate flowback post fracturing

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N05	Initiate immediate flowback post fracturing	Applicable per well The number of fluid injection induced earth tremors above a given magnitude will increase approximately proportionally to the injected fluid volume. Reducing volumes and implementing flowback immediately after fracturing, where appropriate, would reduce the probability of significant earthquakes. This was observed in the induced seismicity at Preese Hall in the UK. Reference: Green, C., Styles, P., Baptie, B. 2012. Preese Hall shale gas fracturing: review & recommendations for induced seismic mitigation. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/15745/5075-preese-hall-shale-gas-fracturing-review.pdf Flowback would be pumped back to the surface immediately following fracturing.	Operators	Operators would implement flowback immediately after fracturing. Considering that the flowback is usually implemented after fracturing (possibly not immediately) the cost of implementing this measure is not considered to be significant compared to the baseline.	Reduced probability of induced seismicity

Measure Summary N07 Operator to use alternative fracturing fluids to water (e.g. nitrogen, CO2, propane)

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N07	Operator to use alternative fracturing fluids to water (e.g. nitrogen, CO2, propane)	Applicable per well Fracturing technology is in continual development. HVHF techniques have developed considerably in a short timeframe in N America. Alternative fracturing fluids (including the use of gases) are under investigation. The consideration of alternative fluids/gasses to water would be considered as and when techniques become technically and commercially available with the aim of recuing environmental risk. These may include the use of nitrogen, CO2 or propane for fracturing. Furthermore, it is understood that the cost premium of a propane gel frack appears to be between 20% and 50% higher than for water-based fracturing. At present, it is understood that the technology is not cost-effective compared to conventional fracturing and is only feasible in certain areas. Cost is the major factor in why propane gel fracks are not widely used. Other factors are: 1. availability of this technology is limited and the technology is not very mature 2. operators need a source of propane or butane and the pipeline infrastructure in place and located to deliver it to the pads and recover it from the wells during flowback. If trucking of propane is required or it cannot be captured and recycled, costs increase and feasibility reduces 3. there are questions regarding safety linked to managing and transporting increased volumes of flammable liquids and gases. CO2 or N2 could be used in place of propane to address safety concerns, however, this would be expensive due to the additional cost for the gas and transportation.	Operators	Operators would be required to evaluate emerging techniques against 'traditional' HVHF. Costs could be: - research and trials - evaluation of environmental risks - technology development	Potential reduction in environmental impacts/risks (e.g. those relating to water depletion and wastewater treatment/management)

Measure Summary N08 a In the case of an incident/accident significantly affecting the environment:(a) operator informs competent authority immediately

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N08 a	In the case of an incident/accident significantly affecting the environment: (a) operator informs competent authority immediately	Applicable per pad. Rapid reaction to incidents/accidents can increase the efficiency and effectiveness of remediation/mitigation responses. The measure would require the operator to inform the competent authority immediately.	Operators Competant Authority/Regulators	Operators would be required to report incidents/accidents immediately to regulators. Costs would be: - management and staff costs of recording and reporting incidents.	All incidents/accidents will be reported and information eventually available in the public domain (see N08 ii). Lessons may be learned by operators and regulators to enable prevention of reoccurrence.

Measure Summary: N08 b In the case of incident/accident significantly affecting the environment competent authority provides details and information to the public

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N08 b	In the case of an incident/accident significantly affecting the environment: (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	Applicable per pad. Rapid reaction to incidents/accidents can increase the efficiency and effectiveness of remediation/mitigation responses. The availability of such information to the public will also both place pressure on operators to avoid occurrence (e.g. through effective risk management processes) and ensure transparency of information regarding environmental impacts that the public may be affected by. The measure would require the 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 (see also N08 i).	Regulators EU institutions Public	Regulators would be required to report incidents/accidents immediately to EU institutions. Costs would be: - management and staff costs of recording and reporting incidents and making available relevant information to the public EU institutions would be required to report incidents/accidents immediately. Costs would be: - management costs of making relevant information available to the public The public would be made aware of incidents/accidents	All incidents/accidents will be reported and information available in the public domain. Lessons may be learned by operators and regulators to enable prevention of reoccurrence. Increased potential for public scrutiny that may result in increased and more extensive consideration and management/prevention of potential risks.

Measure Summary: N10 Operator responsibility for monitoring, reporting and corrective measures following well closure

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N10	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]	Applicable per pad Responsibilitity for monitoring, reporting and corrective measures regarding wells folowing their closure (temporary or permanent) and prior to transfer of ownership and responsibility to a competant authority. This may be required for a considerable period following closure to ensure longterm well intergrity and to be certain that environmental risk in the longterm is negligible. The operator remains responsible for monitoring, reporting and corrective measures.	Operator Competent authority	The operator would be required to put in place longterm monitoring and reporting requirements on well integrity and environmental parameters (see 3b for indication of monitoring costs elements and 22b for well intergrity testing). Corrective actions would need to be carried out as necessary if required. Costs would be: - long-term monitoring costs - cost of corrective actions (if required) Competent authority - cost of permit managagement	Clear responsibility defined for long-term monitoring, reporting and corrective measures regarding wells following their closure (temporary or permanent) and prior to transfer of ownership and responsibility to a competent authority.

Measure Summary N11 Operator to provide financial guarantee to competent authority to cover costs of any remedial action following transfer of responsibility

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N11	Operator to provide financial guarantee to competent authority to cover costs of any remedial action following transfer of responsibility	Applicable per pad Following a period of post closure monitoring, permits would be relinquished and responsibility for wells would be transferred to the competent authority. Whilst environmental risks at this point will be very low/negligible, the operator would retain a degree of financial responsibility for addressing environmental risks/events that may arise following transfer of responsibility. To ensure adequate resources are available to the competent authority, the operators will provide a financial guarantee to the competent authority to cover costs of remedial action following transfer of responsibility.	Operator Competent authority	The operator would need to establish its approach to and obtain funding to provide a financial guarantee. Costs would be: - obtaining the necessary financial guarantee from investors/banks or own resources The competent authority would need to negotiate and agree the nature and scale of the financial guarantee. Costs would be: - establishing the required scale of financial guarantee and agreeing this with the operator	Adequate financial resources are available to address potential remedial action that may arise in the long-term following transfer of responsibility to the competent authority. Operators provide a guaranteed source of resources for any required remedial action and hence the burden does not fall (entirely) on the MS and competent authority.

Measure Summary: N12 Operator to provide financial contribution to competent authority following closure and abandonment

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N12	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)	Applicable per pad Following closure, abandonment and transfer of responsibility, a degree of assurance monitoring may be required by the competent authority. To ensure that adequate resources are available, the operator would provide a financial contribution to the competent authority at this point. This contribution should be sufficient to cover ongoing monitoring and related activities over a sufficient period [20-30 years].	Operator Competent authority	The operator would need to provide a financial contribution following closure, abandonment and transfer of responsibility. Costs would be: - provision of the required financial contribution to the competent authority to provide the required and agreed monitoring The competent authority would need to negotiate and agree the size of contribution. Costs would be: - establishing the required monitoring costs over the long-term for the particular situation and agreeing this with the operator.	Adequate financial resources are available to address potential monitoring costs that may arise in the long-term following closure, abandonment and transfer of responsibility to the competent authority.

Measure Summary N18 Ensure equipment is compatible with composition of fracturing chemicals

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N18	Ensure equipment is compatible with composition of fracturing chemicals	Applicable per well Chemicals used may not have been tested on equipment. To ensure compatibility of equipment, tests are carried out.	Operators and equipment suppliers/manufacturers.	Time for consulting equipment manufacturers, with chemical suppliers and chemical manufacturers on compatibility and the effects of use. Depending on the outcome of such consultation, the costs may be: i) the use of additional chemical products, for example biocides; ii) substitution of chemicals with alternatives, which may in turn have economic and technical/storage implications. It is likely chemical and equipment manufacturers would undertake ongoing R&D and testing programmes as part of their normal operations, although the use of certain chemicals in UG extraction may still be relatively new and untested.	Avoidance of ongoing damage of equipment; increase in operational lifetime with associated monetary savings; avoidance/reduction of productions stoppages; avoidance/reduction of spillages/failures. Increased testing/R&D likely to lead to the improvement of either the efficacy or environmental safety of certain substances.

Measure Summary N19 Carry out thorough planning and testing of equipment prior to hydraulic fracturing operations

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N19	Carry out thorough planning and testing of equipment prior to hydraulic fracturing operations	Applicable per well Equipment needs to be suitable for use for high pressure hydraulic fracturing and the specific stresses and conditions that the process has. Equipment used is tested prior to operations to ensure suitability.	Operators, equipment and chemical suppliers.	Allow time for equipment testing after installation but prior to start of operations. Cost may be: i) consultation with equipment/substance providers, ii) potential for physical presence of a number of technical specialists from some of the companies concerned, or an overall project manager coordinating contact with several suppliers. iii) Additional costs would be incurred resulting from problems/equipment failures. iv) Monitoring of equipment performance to be undertaken during testing phase.	Avoid delay in start of commercial operations. Avoidance of equipment failure/damage of equipment; avoidance/reduction of production stoppages or spillages/major failures.

Measure Summary N21 Implement precautions to prevent invasive species by cleaning vehicles

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N21	Implement precautions to prevent invasive species by cleaning vehicles	Application per pad Invasive species can be introduced as a result of transportation on vehicles. To minimise the risk of invasive species transfer, vehicles are regularly cleaned.	Operators	A requirement to regularly clean vehicles and manage and dispose of waste water in line with existing regulatory requirements. Costs would be: - vehicle cleaning	Potential for introduction of invasive species is minimised.

Measure Summary N22 Maintain records of well location and depth indefinitely

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N22	Maintain records of well location and depth indefinitely	Applicable per well/pad The long-term integrity of wells needs to be maintained. This includes avoiding the comprising of well integrity by other future UG and non-UG activities. To minimise the risk of long-term integrity being compromised by such activities, records of well location and depth are maintained indefinitely.	Competent authority	Requirement to maintain records in archive or indefinitely. Costs would be: - Archiving of records on well location and depth (and potentially construction, plugs, etc.)	A comprehensive record of wells will be available to enable future UG/non-UG activities that may have potential to influence well integrity to properly consider possible impacts on abandoned wells

Measure Summary: N23 Public disclosure by operators of environmental monitoring, production, incidents and well integrity information

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N23	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	General applicability. As with N03 & N04, access to information for the public will be important to increase understanding of issues and help encourage informed and objective discussion based on the correct key issues. The provision of information regarding environmental monitoring information and well integrity will assist in this. Applies to baseline information through to transfer of responsibility to Competent Authority.	Operators and the public.	Operators would be required to publicly disclose baseline, ongoing monitoring and well integrity information. Costs would be: - website establishment and maintenance - collation of information The public would have increased access to information.	Increased access to relevant information on the baseline, monitoring and well integrity data all stakeholders. Ability to make decisions based on actual rather than theoretical information. Increased potential for public scrutiny that may result in enhanced practices.

Measure Summary N25 Reversal of the burden of proof for unconventional gas operators in the context of liability in case of environmental damage

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N25	Reversal of the burden of proof for unconventional gas operators in the context of liability in case of environmental damage	In environmental cases, it may be more difficult for a plaintiff and easier for a defendant to establish facts concerning the causal link (or the absence of it) between an activity carried out by the defendant and the damage. Reversal of the burden of proof concerning fault or causation in favour of the plaintiff alleviates such difficulty.	Operators and the public.	Operators would be required to prove that environmental damage from chemical usage was not caused by their operations. Costs would be: - provision of monitoring information - carrying out investigations The public would have increased access to information.	Operators would ensure good records are maintained of chemicals used and activities. Increased access to relevant information on the baseline, activities and operations for all stakeholders. Increased incentive for high levels of environmental stewardship and risk reduction. Increased potential for public scrutiny that may result in enhanced practices.

Measure Summary N28 Assessment by the Competent Authority of the technical and financial capacity of an operator

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N28	Assessment by the Competent Authority of the technical and financial capacity of an operator	Competent Authority (CA) to explore technical and financial capacity/capability of operator and their contractors, likely to be undertaken at Pre Qualification or full tender stage for any works. Competent Authority would need to consider the following: - Method statement - Environmental Standards Accreditation and Compliance - Safety record - Risk management measures and contingency planning - Tenderers required to provide technical references - Audited accounts to be provided by tenderer and considered by CA - Financial and Credit rating assessment. - Meeting to determine overall assessment of capability	Operators Competent Authority	Operators would be required to provide information on technical and financial suitability. CA would need to consider and verify information and make a judgement.	Reduced likelihood of selecting an unsound operator and of insolvency/accidents/contractual failures, with associated potential liabilities for CA.

Measure Summary: N29 Financial guarantees by operators for environmental and civil liability covering any accidents or unintended negative impacts

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N29	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)	Financial guarantee related to accidents and negative impacts. See for example Article 30 of CCS Directive (2009/31/EC), which establishes...' the obligation on the operator [of the storage site] to take corrective measures in case of leakages or significant irregularities on the basis of a corrective measures plan submitted to and approved by the competent national authority. Where the operator fails to take the necessary corrective measures, these measures should be taken by the competent authority, which should recover the costs from the operator.	Operator (and their contractors) Competent Authority (CA)	Obtain and maintain suitable insurance cover. Preparation and agreement of legal and insurance documentation. CA would need to consider and review legal documentation,	Limits liability of CA and clarifies extent of liability of operator. CA has legal recourse in the event of environmental accident or where public interest is undermined.

Measure Summary N32 Competent Authorities have available sufficient inspection capacity and appropriately skilled inspectors

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N32	Competent Authorities have available sufficient inspection capacity and appropriately skilled inspectors	CA to consider volume and experience of their staff/workload and identify (re)training needs/recruit accordingly.	Competent Authority	Systematically identify training and recruitment needs. Whilst CA's already undertake these activities, they are likely to be expand to include increased workload related to UG activity.	Avoidance of delays/backlogs in inspections and permit issuance.

Measure Summary N33 Independent inspection during all stages of development of well integrity

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N33	Independent inspection during all stages of development of well integrity	Inspection of well integrity via a third party, likely to be a private contractor. Methods include: - computer imaging software - electromagnetic and ultrasound thickness measurement - down hole cameras	Operators (and their contractors)	Procure independent testing services and incur costs for any remediation associated with findings and flaws.	Avoidance of flaws/failures. Mitigation of damage in the event of well failure. Reduction in likelihood of production stoppages .

Measure Summary N35 Member States implement integrated permitting for unconventional gas

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N35	Member States implement integrated permitting for unconventional gas	Applicable per pad Permitting requirements may be split across a number of process (e.g. planning, operational, exploration, water abstraction, water discharge, etc.). MSs would be required to develop an integrated permitting process enabling operators to make a single or cumulative permit appliucation as the development progresses from exploration through to production across all required permits.	Operators MSs and their competent authorities	Operators would be required to progress permitting through a single integrated system. MSs and their competent authorties would need to developmen administer an integrated permitting process. Costs could be: - developmenet of the integrated system	Operators have a single process resulting in efficiencies. MSs have a single system through which to manage the overall permitting requirements and linked environmental impacts in a holistic and efficient process - avoiding fragmentation and disaggregation of decision-making and enabling consideration of interlinked and cumulative effects.

Measure Summary N36 Operators work together to ensure efficient provision of gas collection and wastewater treatment infrastructure

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N36	Operators work together to ensure efficient provision of gas collection and wastewater treatment infrastructure	Potential collocation, cost sharing or renting of facilities by operator(s).	Operators	Discussion and agreement on arrangements.	Cost saving/more efficient usage of infrastructure facilities. Reduction in overall/cumulative environmental impacts associated with infrastructure construction and use.

Measure Summary N37 Pad construction activities staged to reduce soil erosion and to coincide with low rainfall periods

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N37	Pad construction activities staged to reduce soil erosion and to coincide with low rainfall periods	Stage activities to coincide with periods of below average rainfall (i.e. summer months)	Operators (and their contractors) Competent Authority	Restriction in possible construction start/end dates; potential for constraints on equipment/staff associated with period of peak demand (i.e. Summer months).	Reduction in soil erosion/runoff during well construction period. Reduction in vehicle cleaning requirements, reduction in environmental/visual impact on any neighbouring communities

Measure Summary N38 Maintain operator liability for any pollution arising from wells for a period of 100 years

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N38	Maintain operator liability for any pollution arising from wells for a period of 100 years	Extension of 13c	Operator	Insurance costs associated with extension of liabilities and associated legal advice.	Reduction in liabilities of CA and extension of Operators liabilities. Benefits in terms of public acceptance.

Measure Summary N39 Maintain operator liability for any pollution arising from wells indefinitely

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N39	Maintain operator liability for any pollution arising from wells indefinitely	Extension of 13c	Operator	Insurance costs associated with extension of liabilities and associated legal advice. Potential additional costs may be incurred by Operator in order to further limit areas of potential longer term risk. Potential effect on viability of some wells, depending on the scale of financial implications of Operators accepting this liability.	Reduction in liabilities of CA and extension of Operators liabilities. Potential reduction of risks arising from Operators wishing to reduce insurance costs associated with permanent liability.

Measure Summary N42 Prohibit non-disclosure agreements between local residents and/or landowners and unconventional gas operators

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N42	Prohibit non-disclosure agreements between local residents and/or landowners and unconventional gas operators	Prohibit the use of NDA agreements as a condition of operation. These may, for example, prevent landowners from making public details of operations or potential operations, including their experiences of operations that might affect property prices, insurance availability or ability of mortgages to be secured on properties.	Operators Landowners Local Communities in vicinity of operations	NDAs could not be entered into with specific individuals or groups.	Greater transparency of operations. Public acceptance benefits.

Measure Summary N44 Competent authorities compile regional maps of underground resources

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N44	Competent authorities compile regional maps of underground resources	Aim to reduce conflicts with the potential use by competing resource use (e.g. minerals, water, CCS) by preparing overall resources map.	Operators Other Mineral extraction/energy operators. General Public	Potential reduction in conflicts over resource use. Greater public awareness of overall resources in local area/region.	Potential reduction in conflicts; potential for more efficient strategic planning. Greater public awareness of overall resources in local area/region.

Measure Summary: N45 Member States establish a capability to address groundwater contamination arising from unconventional gas operations

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N45	Members States establish a capability to address groundwater contamination arising from unconventional gas operations. In the case of transboundary aquifers, joint capability established	Establish and maintain appropriate capabilities and facilities to deal with a groundwater contamination incident. Note N32 relates to appropriately skilled staff inspection staff only.	Member State/Competent Authority	Establish and test procedure for dealing with incident, Liaison with similar officers/units in adjoining MS, if appropriate.	Improve speed of response in the event of an incident and potential to limit extent of contamination.

Measure Summary: N46 The European Commission develops criteria/guidance for underground risk assessment

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
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	Preparation and publication of guidance to support Operators and their consultants to prepare suitably robust and consistent risk assessment (RAs), recognising specific risks associated with UG, including groundwater contamination and induced seismicity.	European Commission Operators (and their consultants)	EC will commission or prepare the relevant guidance. Operators/consultants will be required to comply.	Ensure sufficient focus is given to relevant risks. Ensure RAs are suitably detailed, robust and consistent with one another. Will support faster learning rates amongst both consultants and CA who will consider submitted RAs.

Measure Summary N47 Operator demonstrates availability of appropriate wastewater treatment facilities

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N47	Operator demonstrates availability of appropriate wastewater treatment facilities	Evidence supplied that wastewater treatment plants are available with sufficient capacity to treat wastewater arising from activities, or will be provided as part of the project.	Operator	Investigation and preparation of details for submission to CA.	Supports suitable provision of wastewater treatment capacity.

Measure Summary N48 Minimum distance between hydraulic fracture pipes and geological strata containing aquifers and the surface to be determined based on risk assessment

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N48	Minimum distance between hydraulic fracture pipes and geological strata containing aquifers and the surface to be determined based on risk assessment	To prepare minimum standards, thresholds and criteria.	Operators.	Require operator to change operations. Limits on maximum extent of operations.	Reduction in risk of aquifer contamination and/or damage and surface induced seismicity

Measure Summary N49 Strategic planning and staged approach of play development to avoid peaks in water demand

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N49	Strategic planning and staged approach of play development to avoid peaks in water demand	Coordination of well development so water demand at each well pad is staged, avoiding spikes in water demand.	Operators; water supply companies	Operators would incur up front costs to coordinate and manage well development process and it will slow extraction and hence profitability. This may be partially offset by savings associated with more efficient use of equipment and transportation (as they are not required simultaneously to the same extent). There would be a corresponding reduction in requirements for water supply and pressure on infrastructure .	Potential efficient use of equipment including transportation; reduction in pressure on water infrastructure and reduction in sudden demand for water supply. Potential to avoid water supply stoppages or reduce the level of investment requirement to improve existing infrastructure.

Measure Summary N50 Lined open ponds with safety net protecting biodiversity

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N50	Lined open ponds with safety net protecting biodiversity	Lined ponds using geomembrane to contain wastewater. Installation of safety net over open ponds so wildlife is protected.	Operators	Cost of purchasing and installation of pond, geomembrane and netting. Periodic monitoring, cleaning and potential replacement of netting.	Avoidance of surface water and groundwater pollution from waste water through containment. Protection of wildlife (and people) from hazard of falling into open ponds.

Measure Summary N51 Consider wastewaters hazardous unless operator demonstrates otherwise

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N51	Consider wastewaters hazardous unless operator demonstrates otherwise	Standard assumption that wastewater from UG operations are hazardous and require treatment according to relevant hazardous waste regulations.	Operators/Competent Authority.	Impact will differ if operator is able to demonstrate if wastewaters are hazardous or not. Assuming operator is able: costs will be incurred in collection of evidence and dialogue with competent authority. If operator is not able additional costs incurred through storage,collection and disposal, record keeping and associated environmental permitting. Competent Authority would need to consider permitting applications and enforce regulation.	More stringent treatment of wastewater will reduce the likelihood of contamination/environmental damage.

Measure Summary N52 Ban injection of wastewaters into geological formations for disposal

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N52	Ban injection of wastewaters into geological formations for disposal	It is to be noted that under current EU legislation, direct discharges of pollutants into groundwater are prohibited under the Water Framework Directive.	Operators	Increase the volume of water requiring storage, transportation and treatment prior to discharge to surface water.	Reduce the potential for contamination of groundwater.

Measure Summary N53 Consider wastewaters from unconventional gas operations as hazardous waste

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N53	Consider wastewaters from unconventional gas operations as hazardous waste	Similar measure to N51, but more stringent. All wastewater from UG operations are hazardous and require treatment according to relevant hazardous waste regulations, irrespective of evidence supplied by Operators.	Operators/ Competent Authority.	Costs will be incurred through storage, collection and disposal, record keeping and associated environmental permitting. Competent Authority would need to consider permitting applications and enforce regulation.	More stringent treatment of wastewater will reduce the likelihood of contamination/environmental damage.

Measure Summary N54 Encourage industry voluntary approach to reduce air pollutants and greenhouse gases

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
N54	Encourage industry voluntary approach to reduce air pollutants and greenhouse gases	Establish and implement voluntary code of conduct/best practice approach to minimising emissions throughout project life cycle.	Operators, Competent Authorities.	Potential changes to operational processes - offset by potential savings through more efficient use of resources and infrastructure. Some costs may be borne by Competent Authorities through awareness raising and publicising best practice to support uptake.	Reduction of GHG and air pollution alongside potential operational cost savings.

Measure Summary: CAH1 Chemical safety assessment / biocide risk assessment

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CAH1	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	This measure is additional to other measures designed to lead to chemical safety assessments (REACH) or risk assessments (biocides) being madae more specific to hydraulic fracturing (CAL1/2/3, CAM1)	Operators (downstream users of chemicals in HF). It is presumed that the substance manufacturers/importers would not be able or willing to undertake such an assessment.	This is a scientifically challenging issue (assessing mixture toxicity / ecotoxicity). Companies would need to review the specific chemicals to be used in HF and to identify the nature and extent of any potentially synergistic or antagonistic effects on target organisms (humans or biota).	Assuming that appropriate risk management measures would be adopted as a result of the assessment, the benefits would be reduced potential for harm to health and/or the environment arising from mixture toxicity. No specific examples of chemicals used in HF having such cumulative, etc. effects has been identified.

Measure Summary: CSL1 Non-use of products / substances

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CSL1a	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as CMR (carcinogenic, mutagenic or toxic for reproduction) category 1A or 1B	Would prevent such substances from being used in hydraulic fracturing (including refracturing). Classifications are as per the CLP Regulation 1272/2008. It would also require the same for use of substances that do not have EU harmonised classification but which have notified "self-classification" in any of the relevant hazard classes of the Regulation.	Operators.	Operators would not be able to use certain chemical substances and therefore would need to identify alternative substances that may be more expensive to use or that do not deliver a similar level of technical performance to the original substances. Cost could be: - increased cost of chemicals - reduced efficiency of gas extraction or other operations (impacts on well productivity are likely to far outweigh differences in prices between chemicals) This goes substantially beyond existing legislation, which does not include a prescriptive requirement to substitute such chemicals (e.g. under Directive 98/24/EC)	Assurance that if spills or leaks of chemicals did occur and resulted in releases to the environment (surface water and groundwater), that environmental pollution risk (from these substances) would be prevented. Reduced potential for adverse health impacts on workers.
CSL1b	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	Would prevent such substances from being used in hydraulic fracturing (including refracturing). Classifications are as per the CLP Regulation 1272/2008. It would also require the same for use of substances that do not have EU harmonised classification but which have notified "self-classification" in any of the relevant hazard classes of the Regulation.	Operators.	Operators would not be able to use certain chemical substances and therefore would need to identify alternative substances that may be more expensive to use or that do not deliver a similar level of technical performance to the original substances. Cost could be: - increased cost of chemicals - reduced efficiency of gas extraction or other operations (impacts on well productivity are likely to far outweigh differences in prices between chemicals) This goes substantially beyond existing legislation, which does not include a prescriptive requirement to substitute such chemicals (e.g. under Directive 98/24/EC)	Assurance that if spills or leaks of chemicals did occur and resulted in releases to the environment (surface water and groundwater), that environmental pollution risk (from these substances) would be prevented. Reduced potential for adverse health impacts on workers.
CSL1c	Non-use of any (non-biocidal) substances with [harmonised or notified] classification as aquatic acute category 1 or aquatic chronic category 1	Would prevent such substances from being used in hydraulic fracturing (including refracturing). Classifications are as per the CLP Regulation 1272/2008. It would also require the same for use of substances that do not have EU harmonised classification but which have notified "self-classification" in any of the relevant hazard classes of the Regulation. It may be necessary to allow for certain derogations where specific substances are necessary on technical grounds. It is assumed not to allow derogation on economic grounds.	Operators.	Operators would not be able to use certain chemical substances and therefore would need to identify alternative substances that may be more expensive to use or that do not deliver a similar level of technical performance to the original substances. Cost could be: - increased cost of chemicals - reduced efficiency of gas extraction or other operations (impacts on well productivity are likely to far outweigh differences in prices between chemicals) This goes substantially beyond existing legislation, which does not include a prescriptive requirement to substitute such chemicals (e.g. under Directive 98/24/EC)	Assurance that if spills or leaks of chemicals did occur and resulted in releases to the environment (surface water and groundwater), that environmental pollution risk (from these substances) would be prevented.

CSL1d	Non-use in biocidal products of any substances with [harmonised or notified] classification as aquatic acute category 1 or aquatic chronic category 1	Would prevent such substances from being used in hydraulic fracturing (including refracturing). Classifications are as per the CLP Regulation 1272/2008. It would also require the same for use of substances that do not have EU harmonised classification but which have notified "self-classification" in any of the relevant hazard classes of the Regulation. It may be necessary to allow for certain derogations where specific substances are necessary on technical grounds. It is assumed not to allow derogation on economic grounds.	Operators.	Operators would not be able to use certain chemical substances and therefore would need to identify alternative substances that may be more expensive to use or that do not deliver a similar level of technical performance to the original substances. Cost could be: - increased cost of chemicals - reduced efficiency of gas extraction or other operations (impacts on well productivity are likely to far outweigh differences in prices between chemicals) This goes substantially beyond existing legislation, which does not include a prescriptive requirement to substitute such chemicals (e.g. under Directive 98/24/EC)	Assurance that if spills or leaks of chemicals did occur and resulted in releases to the environment (surface water and groundwater), that environmental pollution risk (from these substances) would be prevented.

Measure Summary CSL2 Non-use of any substances on REACH Candidate List for authorisation (substances of very high concern)

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CSL2	Non-use of any substances on REACH Candidate List for authorisation (substances of very high concern)	Would prevent such substances from being used in hydraulic fracturing (including refracturing). These substances are included at: http://echa.europa.eu/candidate-list-table The list includes substances that are CMR category 1A/1B; persistent, bioaccumulative and toxic (PBT) substances; very persistent very bioaccumulative (vPvB) substances; and substances of equivalent concern (however, not all such substances are yet included). The measure is could be an alternative to CSL1. It goes beyond and could potentially be contradictory with existing legislation. It is assumed that some delay (e.g. 6m to 1yr) would be required between inclusion of substances on the list and a requirement for companies to stop using the substances (to prevent immediate cessation of production). This measure goes significantly beyond the baseline as such substances may continue to be used. Even if/when Candidate List substances are selected for inclusion in Annex XIV of REACH, they may still be used until the sunset date (several years) or after the sunset date if an authorisation is applied for and granted.	Operators.	Operators would not be able to use certain chemical substances and therefore would need to identify alternative substances that may be more expensive to use or that do not deliver a similar level of technical performance to the original substances. Cost could be: - increased cost of chemicals - reduced efficiency of gas extraction or other operations (impacts on well productivity are likely to far outweigh differences in prices between chemicals) This goes substantially beyond existing legislation, which does not include a prescriptive requirement to substitute such chemicals.	Assurance that if spills or leaks of chemicals did occur and resulted in releases to the environment (surface water and groundwater), that environmental pollution risk (from PBT and CMR substances) would be prevented.

Measure Summary CSL4 Demonstration that all steps practicable have been taken to reduce number, concentration and volume of chemicals used in hydraulic fracturing

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CSL4	Demonstration that all steps practicable have been taken to reduce number, concentration and volume of chemicals used in hydraulic fracturing	This measure is highly specific to the situation in question (e.g. geochemical conditions). The primary aim is to ensure that operators consider and implement options to reduce chemical use. The demonstration of this is a means of checking that this has been done.	Operators and regulatory authorities.	Operators would need to assess the potential to reduce chemical use specific to an individual gas concession/play and potentially at well level if there are differences. They would then need to take steps to achieve such reductions and demonstrate that this has been done to the authorities. The costs associated with this would be the operator's time, as well as potential lost revenue through reduced productivity of wells. There would be benefits to the operator through reduced chemical purchase costs. Regulators would incur the costs associated with the time needed to check and challenge the operator's demonstration.	Reduced use of chemicals in lower concentration would lead to reduced hazard and hence reduced risk to the environment.

Measure Summary CSL5 Authorities to organise an exchange of views/information on environmentally safer technologies and alternatives to the use of chemicals in hydraulic fracturing

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CSL5	Authorities to organise an exchange of views/information on environmentally safer technologies and alternatives to the use of chemicals in hydraulic fracturing	This could be done through, for example, similar information exchange processes to those that exist under other legislation (e.g. IPPC directive, Solvent Emissions Directive). Information could be exchanged amongst competent authorities, industry and other experts in the field.	Operators and regulatory authorities.	Authorities would need to administer the exchange of information. Participation in the process would be voluntary and the actual response of the UG industry is not possible to predict.	Potential increased chance of uptake of lower hazard/risk chemicals (or avoidance of chemicals use) in hydraulic fracturing due to increased awareness of good practices.

Measure Summary: CSM1 Non-use of biocidal/non-biocidal substances with classification as carcinogenic, mutagenic or toxic for reproduction

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CSM1a	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	Measure is the same as CSL1a but would also require non-use of substances with classification as CMR category 2. Applies to non-biocide substances. In addition to substances classified as CMR category 1A or 1B, those in category 2 would also be prohibited from use. Would prevent such substances from being used in hydraulic fracturing (including refracturing). Classifications are as per the CLP Regulation 1272/2008. It would also require the same for use of substances that do not have EU harmonised classification but which have notified "self-classification" in any of the relevant hazard classes of the Regulation. This would require a longer list of chemicals to be avoided than covered in CSL1a.	Operators.	Operators would not be able to use certain chemical substances and therefore would need to identify alternative substances that may be more expensive to use or that do not deliver a similar level of technical performance to the original substances. Cost could be: - increased cost of chemicals - reduced efficiency of gas extraction or other operations (impacts on well productivity are likely to far outweigh differences in prices between chemicals) The costs would tend to be greater than for CSL1a (i.e. potentially greater impacts due to reduced substance choice). This goes substantially beyond existing legislation, which does not include a prescriptive requirement to substitute such chemicals (e.g. under Directive 98/24/EC)	Assurance that if spills or leaks of chemicals did occur and resulted in releases to the environment (surface water and groundwater), that environmental pollution risk from these substances would be prevented. Greater level of health/environmental protection assured than under CSL1a. Reduced potential for adverse health impacts on workers.
CSM1b	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	Measure is the same as CSL1b but would also require non-use of substances with classification as CMR category 2. Applies to substances in biocidal products. In addition to substances classified as CMR category 1A or 1B, those in category 2 would also be prohibited from use. Would prevent such substances from being used in hydraulic fracturing (including refracturing). Classifications are as per the CLP Regulation 1272/2008. It would also require the same for use of substances that do not have EU harmonised classification but which have notified "self-classification" in any of the relevant hazard classes of the Regulation. This would require a longer list of chemicals to be avoided than covered in CSL1b.	Operators.	Operators would not be able to use certain chemical substances and therefore would need to identify alternative substances that may be more expensive to use or that do not deliver a similar level of technical performance to the original substances. Cost could be: - increased cost of chemicals - reduced efficiency of gas extraction or other operations (impacts on well productivity are likely to far outweigh differences in prices between chemicals) The costs would tend to be greater than for CSL1b (i.e. potentially greater impacts due to reduced substance choice). This goes substantially beyond existing legislation, which does not include a prescriptive requirement to substitute such chemicals (e.g. under Directive 98/24/EC)	Assurance that if spills or leaks of chemicals did occur and resulted in releases to the environment (surface water and groundwater), that environmental pollution risk from these substances would be prevented. Greater level of health/environmental protection assured than under CSL1b. Reduced potential for adverse health impacts on workers.

Measure Summary: CSM1 Non-use of biocidal/non-biocidal substances with classification as carcinogenic, mutagenic or toxic for reproduction

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CSM1c	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	Measure is the same as CSL1c but would also require non-use of substances with classification as category 2 for acute or chronic aquatic toxicity. Applies to non-biocide substances. Would prevent such substances from being used in hydraulic fracturing (including refracturing). Classifications are as per the CLP Regulation 1272/2008. It would also require the same for use of substances that do not have EU harmonised classification but which have notified "self-classification" in any of the relevant hazard classes of the Regulation. This would require a longer list of chemicals to be avoided than covered in CSL1c. It may be necessary to allow for certain derogations where specific substances are necessary on technical grounds. It is assumed not to allow derogation on economic grounds.	Operators.	Operators would not be able to use certain chemical substances and therefore would need to identify alternative substances that may be more expensive to use or that do not deliver a similar level of technical performance to the original substances. Cost could be: - increased cost of chemicals - reduced efficiency of gas extraction or other operations (impacts on well productivity are likely to far outweigh differences in prices between chemicals) The costs would tend to be greater than for CSL1c (i.e. potentially greater impacts due to reduced substance choice). This goes substantially beyond existing legislation, which does not include a prescriptive requirement to substitute such chemicals (e.g. under Directive 98/24/EC)	Assurance that if spills or leaks of chemicals did occur and resulted in releases to the environment (surface water and groundwater), that environmental pollution risk from these substances would be prevented. . Greater level of health/environmental protection assured than under CSL1c.
CSM1d	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	Measure is the same as CSL1d but would also require non-use of substances with classification as category 2 for acute or chronic aquatic toxicity. Applies to substances in biocidal products. Would prevent such substances from being used in hydraulic fracturing (including refracturing). Classifications are as per the CLP Regulation 1272/2008. It would also require the same for use of substances that do not have EU harmonised classification but which have notified "self-classification" in any of the relevant hazard classes of the Regulation. This would require a longer list of chemicals to be avoided than covered in CSL1d. It may be necessary to allow for certain derogations where specific substances are necessary on technical grounds. It is assumed not to allow derogation on economic grounds.	Operators.	Operators would not be able to use certain chemical substances and therefore would need to identify alternative substances that may be more expensive to use or that do not deliver a similar level of technical performance to the original substances. Cost could be: - increased cost of chemicals - reduced efficiency of gas extraction or other operations (impacts on well productivity are likely to far outweigh differences in prices between chemicals) The costs would tend to be greater than for CSL1d (i.e. potentially greater impacts due to reduced substance choice). This goes substantially beyond existing legislation, which does not include a prescriptive requirement to substitute such chemicals (e.g. under Directive 98/24/EC)	Assurance that if spills or leaks of chemicals did occur and resulted in releases to the environment (surface water and groundwater), that environmental pollution risk from these substances would be prevented. Greater level of health/environmental protection assured than under CSL1d.

Measure Summary CSM3 Selection of substances (chemicals and proppants) that minimise the need for treatment when present in flowback water

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CSM3	Selection of substances (chemicals and proppants) that minimise the need for treatment when present in flowback water	This measure is based on AEA (2012) and involves selection of proppants which increase porosity inside the fracture. These can reportedly be beneficial in reducing the extent of treatment required. A sieve analysis can be carried out to assist in identifying the most appropriate proppant for use in a specific application (AEA, 2012). This is reported to be an "Industry best practice measure under consideration".	Operators	Potential price differences through choice of proppants on the basis of potential to reduce need for treatment of water. Potential implications for well productivity. Both may be positive or negative depending on the alternative selected. Also costs associated with research on potential alternative chemicals and proppants.	Reduced need for treatment of fluids so reduced costs and reduced emissions to environment.

Measure Summary: CSM4 Establish general principals for the use of chemicals

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CSM4	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.	Such principles could be written into existing or new legislation in a similar manner to principles under for example the Chemical Agents Directive or Carcinogens and Mutagens Directive.	Operators	There would be a formal obligation on operators to consider (and demonstrate that they have considered) the use of lower hazard/risk solutions to the use of chemicals and to substitute / reduce use of chemicals where feasible.	Increased chance that, if spills or leaks of chemicals did occur and resulted in releases to the environment (surface water and groundwater), environmental pollution risk from these substances would be prevented.

Measure Summary CSH1 Use of water or inert materials only in hydraulic fracturing

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CSH1	Use of water or inert materials only in hydraulic fracturing	All of the chemicals typically used would no longer be permitted. Note that there is relatively little evidence on the extent to which this is possible in practice. See e.g. http://www.anglocelt.ie/news/roundup/articles/2012/05/16/4010456-chemicalfree-fracking-not-investigated-by-university-report and http://www.anglocelt.ie/news/roundup/articles/2012/05/03/4010290-report-on-chemicalfree-fracking-due-next-week/	Operators	There would presumably be costs associated with e.g. Reduced productivity due to inability to use surfactants; increased equipment corrosion due to inability to use biocides. The extent of this cannot currently be quantitied.	Environmental and human exposure to chemicals in HVHF fluids would be removed.

Measure Summary: CSH2 Non-use of any biocidal/non-biocidal substances with classification for any health or environmental effects

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CSH2a	Non-use of any (non-biocidal) substances with [harmonised or notified] classification for any health or environmental effects	Under this measure, chemicals could not be used in hydraulic fracturing if they have any hazard classification for health or environmental effects. Would prevent such substances from being used in hydraulic fracturing (including refracturing). Classifications are as per the CLP Regulation 1272/2008. It would also require the same for use of substances that do not have EU harmonised classification but which have notified "self-classification" in any of the relevant hazard classes of the Regulation.	Operators.	Operators would not be able to use certain chemical substances and therefore would need to identify alternative substances that may be more expensive to use or that do not deliver a similar level of technical performance to the original substances. Cost could be: - increased cost of chemicals - reduced efficiency of gas extraction or other operations (impacts on well productivity are likely to far outweigh differences in prices between chemicals)	Assurance that if spills or leaks of chemicals did occur and resulted in releases to the environment (surface water and groundwater), that environmental pollution risk from these substances would be prevented. Greater level of health/environmental protection assured than under CSL1a-d or CSM1a-d. Reduced potential for adverse health impacts on workers.
CSH2b	Non-use in biocidal products of any substances with [harmonised or notified] classification for any health or environmental effects	Under this measure, chemicals could not be used in hydraulic fracturing if they have any hazard classification for health or environmental effects. Would prevent such substances from being used in hydraulic fracturing (including refracturing). Classifications are as per the CLP Regulation 1272/2008. It would also require the same for use of substances that do not have EU harmonised classification but which have notified "self-classification" in any of the relevant hazard classes of the Regulation. This would require a longer list of chemicals to be avoided than covered in the low and medium ambition level measures.	Operators.	Operators would not be able to use certain chemical substances and therefore would need to identify alternative substances that may be more expensive to use or that do not deliver a similar level of technical performance to the original substances. Cost could be: - increased cost of chemicals - reduced efficiency of gas extraction or other operations (impacts on well productivity are likely to far outweigh differences in prices between chemicals) The costs would tend to be greater than for measures CSL1b, CSL1d, CSM1b and CSM1d (i.e. potentially greater impacts due to reduced substance choice). This goes substantially beyond existing legislation, which does not include a prescriptive requirement to substitute such chemicals (e.g. under Directive 98/24/EC)	Assurance that if spills or leaks of chemicals did occur and resulted in releases to the environment (surface water and groundwater), that environmental pollution risk from these substances would be prevented. Greater level of health/environmental protection assured than under CSL1a-d or CSM1a-d. Reduced potential for adverse health impacts on workers.

Measure Summary: CDL1 Disclosure of information to Competent Authority (chemicals)

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CDL1	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	Would allow scrutiny of which chemicals are used as a pointer to possible sources of risk	Operators and competent authorities	Operators - provide details of the chemical substances used to the CA. This may require collection of additional information (e.g. CAS numbers of components of substance and impurities) from supply chain. Competent authority - Receive and review information.	Additional scrutiny of which chemicals are being used. Provides some ability to demonstrate liability in the event of environmental contamination. Also provides an incentive for operator to use less hazardous substances and to ensure appropriate information is collected from supply chain on which chemicals are used (rather than trade names)

Measure Summary: CDL2 Disclosure of information to the public (list of chemicals potentially used)

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CDL2	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	Would allow scrutiny of which chemicals are used as a pointer to possible sources of risk. Would not necessarily require any more information than trade names (as in the case of some existing/older disseminated information).	Operators and public	Operators - provide details of the chemical substances used to the public. Without specifying exactly what information must be provided, companies may only provide information immediately to hand e.g. trade names. Provide information on company website. General public - opportunity to scrutinise and highlight issues with chemicals used. Public authorities - potential costs of developing a centralised database of such information.	Additional scrutiny of which chemicals are being used. Provides some ability to demonstrate liability in the event of environmental contamination. Also provides an incentive for operator to use less hazardous substances and to ensure appropriate information is collected from supply chain on which chemicals are used (rather than trade names)

Measure Summary: CDM1 Disclosure of information to Competent Authority (chemicals)

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CDM1	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	Would allow scrutiny of which chemicals are used as a pointer to possible sources of risk. Provides a greater degree of resolution and more information than CDL1.	Operators and competent authorities	Operators - provide details of the chemical substances used to the CA. This would require collection of additional information (e.g. CAS numbers of components of substance and impurities) from supply chain but also reliable and robust recording of information of which chemicals are used, when and in what quantities. Costs to operators are greater than for CDL1. Competent authority - Receive and review information.	Additional scrutiny of which chemicals are being used. Provides some ability to demonstrate liability in the event of environmental contamination. Also provides an incentive for operator to use less hazardous substances and to ensure appropriate information is collected from supply chain on which chemicals are used (rather than trade names) Benefits are greater than CDL1 due to increased ability to track any contamination issues to a more specific location and time.

Measure Summary: CDM2 Disclosure of information to the public (list of chemicals potenially and actually used)

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CDM2	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	Would allow scrutiny of which chemicals are used as a pointer to possible sources of risk. Would require specific chemical names and CAS numbers which goes beyond some past examples of chemical disclosure from other regions.	Operators and public	Operators - provide details of the chemical substances used to the public. Provide information on company website and public dissemination portal. Potential cost associated with greater pressure to substitute chemicals used and hence implications for relative price/cost of alternatives and possible implications for well productivity Also potential cost associated with loss of confidential information to competitors who would know which chemicals are being used in which specific locations. General public - opportunity to scrutinise and highlight issues with chemicals used, in more detail than CDL2. Public authorities - required costs of developing and maintaining a centralised database of such information.	Additional scrutiny of which chemicals are being used. Provides improved ability to demonstrate liability in the event of environmental contamination compared to CDL1 (due to more precise location and information on specific chemicals) and also ability for public, NGOs, etc. to scrutinise potential environmental risks in more detail. Also provides an incentive for operator to use less hazardous substances and to ensure appropriate information is collected from supply chain on which chemicals are used (rather than trade names)

Measure Summary: CDH1 Disclosure of information to the public (chemicals and fracture fluid)

Ref	Measure description	Measure detail	Who would be affected	How would they be affected?	Benefits
CDH1	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	Would allow scrutiny of which chemicals are used as a pointer to possible sources of risk. Would require extensive information on chemical use to be disclosed, seemingly more than is typically available in other regions (www.fracfocus.org.)	Operators and public	Operators - provide details of the chemical substances used (and how, when, etc.) to the public. Provide information on company website and public dissemination portal. Potential cost associated with greater pressure to substitute chemicals used and hence implications for relative price/cost of alternatives and possible implications for well productivity Also cost associated with loss of confidential information to competitors who would know which chemicals are being used in which specific locations, along with other potentially proprietary information on operations. General public - opportunity to scrutinise and highlight issues with chemicals used, in more detail than CDM2. Public authorities - required costs of developing and maintaining a centralised database of such information.	Additional scrutiny of which chemicals are being used. Provides improved ability to demonstrate liability in the event of environmental contamination compared to CDL1 and CDM2 (due to more precise information on timing, location, etc. on specific chemicals) and also ability for public, NGOs, etc. to scrutinise potential environmental risks in more detail. Also provides an incentive for operator to use less hazardous substances and to ensure appropriate information is collected from supply chain on which chemicals are used (rather than trade names)

Appendix E
Business as Usual and Normal Practice Measures

Table E1 Business as Usual Measures

Ref.	Measure Title
Underground Risks	
13a	Operators to draw up a plan for closure of a waste facility[50] (i.e. check that the waste facility ensures short and long term safe disposal; close the waste facility)
27f	Operators keep records of all waste management operations and make them available for inspection (e.g. of flowback, produced water management)
28c	Reporting of major accidents to a competent authority for Category A waste facilities covered under Mining Waste Directive
Chemical Usage	
CAB1	REACH registration (for substances subject to registration), including chemical safety assessment for relevant substances to demonstrate safe use (by chemical manufacturer/importer)
CAB2	Downstream user (operator) complies with risk management measures in REACH registration (for substances subject to registration)
CAB3	Approval of biocidal active substance and authorisation of biocidal products for defined product types based on assessment of risks
CSB1	Avoid substances not registered under REACH for the relevant use (unless exempted from REACH registration)
CSB2	If use of substances subject to restriction (Annex XVII) , comply with the conditions for restriction; if use of 'substances of very high concern', comply with the conditions for authorisation (for substances on Annex XIV) of REACH
CSB3	Avoid biocidal active substances without approval and biocidal products without authorisation
CDB1	Identified (potential) uses of substances registered under REACH made available to public on ECHA website per substance
CDB2	Chemical suppliers provide safety data sheet to operator for relevant substances, including (eco)toxicological hazard and properties data, with exposure scenario and required risk management measures
CDB3	REACH competent authority can access data available on substances used by operator
Surface Water	
33k	Technical development and training of staff for the management of waste facilities (e.g. pollution prevention training)
Waste	
10a	Characterisation of waste and wastewaters by operator prior to treatment
30f	Traceability of hazardous waste from production to final destination
36d	Require wastewater treatment/processing: i) processing of flowback for recycling ii) treatment of flowback for discharge to surface water

[50] Designated structures - whether natural or artificial - where extractive waste is intentionally accumulated or deposited, qualify as 'waste facilities', under Dir. 2006/21/EC. This covers underground structures designated by the operator as areas where residuals of fracturing fluids remain after the fracturing operations.

Ref.	Measure Title
36e	Duty of care / chain of custody arrangements for waste transfer between Member States or to third countries
Post Closure	
29d	Site inspection and assessment prior to and after closure of waste facilities
43a	Land affected by a waste facility is rehabilitated
43b	Post closure waste facility monitoring
43d	Post closure waste facility maintenance
Other	
14a	Operators provide a financial guarantee or equivalent prior to waste management operations
42a	Environmental Impact Assessment for pipelines (above specified threshold)
N14	Mandatory Environmental Impact Assessment for all projects involving extraction of over 500,000m^3 gas per day. Assessment of whether deep drilling projects and surface industrial installations for gas extraction are likely to have significant effects on the environment regardless of amount extracted (screening)

Table E2 Non-BAU Measures that might be adopted under Normal Practice by Industry

Ref.	Measure Description
Zoning	
1a	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
1b	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
Underground Risks	
N55	Conduct 2D seismic survey to identify faults and fractures
3a iii	Site baseline Undertake sampling of groundwater
3a x-a2	Site baseline Geological, hydrogeological and seismic conceptual model [2] Obtain geomechanical information on fractures, stress, rock strength, in situ fluid pressures
3a x-a7	Site baseline Geological, hydrogeological and seismic conceptual model [7] Obtain data on area, thickness, capacity, porosity and permeability of formations.
3a xi	Site baseline Establish the presence of methane in groundwater, including drinking water
3a xiii	Site baseline Undertake assessment of existing underground wells and structures
3b iii	Monitoring Undertake monitoring of groundwater

Ref.	Measure Description
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)
22b ii	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: 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: iii) mechanical integrity testing of equipment (MIT)
22b iv	Integrity testing at key stages in well development e.g. before/during/after all HF events, including: iv) casing inspection test and log
22d	Search for and document potential leakage pathways (e.g. other wells, faults, mines)
26g	Implementation of remedial measures if well failure occurs
Chemical Use	
CDL2	Disclosure of information to 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
CDM1	Disclosure of information to Competent Authority: declaration of substance name, CAS number, concentrations, precise 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
Water Depletion	
3a vi	Site baseline Establish water source availability and test for suitability
38b	Demand profile for water
38c	Water management plan
Surface Water	
3b ii	Monitoring Undertake monitoring of surface water bodies in wet and dry periods
29a	Good practice construction / deconstruction practices, including design for well abandonment
33a	Good site practice to prevention of leaks and spills
33b	Use of tank level alarms
33d	Spill kits available for use

Ref.	Measure Description
33f	Impervious site liner under pad with puncture proof underlay
33g	Collection and control of surface runoff
33i	Good site security
Air Quality	
3a i	Site baseline Undertake sampling of air quality
17c	Flares or incinerators to reduce emissions from fracturing fluid at exploration stage (where not connected to gas network)
Waste	
3b xiv	Monitoring Undertake monitoring of flowback water return rate and characterise
3b xv	Monitoring Undertake monitoring (volume and characterisation) of produced water volume and treatment solution
27c i [51]	Injection of flowback and produced water into designated formations for disposal, provided specific conditions are in place i) treated waste water
27c ii [52]	Injection of flowback and produced water into designated formations for disposal, provided specific conditions are in place ii) untreated waste water
30c	Use of closed loop system to contain drilling mud
36c	Treatment requirements for wastewater and capability of treatment works to treat wastewater established
Post Closure[53]	
N22	Maintain records of well location and depth indefinitely
12	Specific risk assessment, well plugging, inspection and monitoring requirements (e.g. for releases to air, well integrity, periodicity of inspections, wellhead monitoring every 90 days)
13b i	Specific post closure well inspection, maintenance and monitoring/reporting programme (i) following detection of possible pollution (low ambition)
13b ii	Specific post closure well inspection, maintenance and monitoring/reporting programme (ii) periodic inspection and monitoring (high ambition)
13d ii	Abandonment survey Undertake sampling of surface water bodies near the pad

[51] It is to be noted that under current EU legislation, direct discharges of pollutants into groundwater are prohibited under the Water Framework Directive (2000/60/EC) and the Mining Waste Directive (2006/21/EC) applies to the management of extractive waste both at the surface and in the underground.

[52] See footnote 51.

[53] The Mining Waste Directive includes provisions on closure and post-closure of waste facilities. Measures included under the options (see section 3.9) would include more specific provisions.

Ref.	Measure Description	
13d iii	Abandonment survey Undertake sampling of groundwater near the pad	
13d iv	Abandonment survey Obtain data on drinking water abstraction points (wells, boreholes, springs, surface water abstraction points)	
13d ix	Abandonment survey Undertake assessment of ex-anti underground wells and structures	
13d v	Abandonment survey Undertake land condition (soil) survey around pad	
26g	Implementation of remedial measures if well failure occurs	
29a	Good practice construction / deconstruction practices, including design for well abandonment	
Public Acceptance		
15a i	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment)	
15a ii	Public consultation and engagement by operators: (ii) for permitting	
Other Measures		
29e	Management	Site reinstatement plan
51e	Noise	Vehicle routes specified
N08a	Incident	In the case of an incident/accident significantly affecting the environment, (a) operator informs competent authority immediately
N08b	Incident	In the case of an incident/accident significantly affecting the environment, (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
N18	Equipment	Ensure equipment is compatible with composition of fracturing chemicals
N19	Equipment	Carry out thorough planning and testing of equipment prior to hydraulic fracturing operations
N31	Inspection	Inspections by Competent Authorities during all stages of development (e.g. of well completion reports and environmental risk management and controls)
3a iv	Baseline	Site baseline Obtain data on drinking water abstraction points (wells, boreholes and springs)
3a v	Transport	Site baseline Undertake land condition (soil) survey around pad
3a vii	Transport	Site baseline Undertake transport and traffic study.
3a xii	Baseline	Site baseline Undertake assessment of land use, infrastructure and buildings
3b iv	Monitoring	Monitoring Undertake monitoring of drinking water abstraction points (wells, boreholes, springs, surface water)
3b xix	Incident	Monitoring Undertake monitoring of spills volume, nature, location and clean-up (including reporting)
9a	Incident	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

Ref.	Measure Description	
9b	Incident	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
51a	Noise	Maximum noise levels specified
51c	Noise	Noise screening installation: (i) screen drilling and fracturing rigs with noise barrier / enclosure; (ii) acoustic fencing around the site perimeter.
59a	Transport	Traffic impact assessment including consideration of noise, emissions and other relevant impacts
59b	Transport	Transport management plan (including consideration of available road, rail, waterway infrastructure)

Appendix F
Policy Options and Related Measures

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	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 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 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 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 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 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 adequately implemented by Member States.	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 excepted.	Qual	HM	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	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 or mining activities)	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
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	23	L	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)	Through delivery of 3 a x detail	Quant	MM	No	1	1	1	1	1
Underground Risks	N/A	26e	26e	24	-	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	25	-	Implementation of remedial measures if well failure occurs	0	0	Qual	MM	Yes	1	1	1	1	1
Underground Risks	N/A	55c	55c	26	-	Ground motion prediction models to assess the potential impact of induced earthquakes	0	0	Quant	MM	No	-	-	-	-	-
Underground Risks	N/A	N09	N09	27	-	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	28	-	Initiate immediate flowback post fracturing	0	0	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
Underground Risks	N/A	N46	N46	29	-	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	30	-	Operator to use alternative fracturing fluids to water (e.g. nitrogen, CO2, propane)	0	0	Qual	MH	No	-	-	-	-	-
Underground Risks	N/A	55h	55h	31	-	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
Underground Risks	N/A	22a	22a	32	-	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)	0	Measures to be split out for cost purposes	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22b	22b i	33	-	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	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	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	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	iii) mechanical integrity testing of equipment (MIT)	0	Quant	HH	Yes	-	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
Underground Risks	N/A	22b	22b iv	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	iv) casing inspection test and log	0	Quant	HH	Yes	-	1	1	1	1
Underground Risks	N/A	22c	22c	37	-	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	38	-	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	39	-	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	40	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	41	-	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
Underground Risks	N/A	3a	3a iii	42	L	Site baseline Undertake sampling of groundwater	LOW 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	3a	3a iii	43	H	Site baseline Undertake sampling of groundwater	HIGH AMIBITION Borehole to sample deep groundwater and characterise the hydrological series	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	44	-	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	45	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	46	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	47	-	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	48	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	49	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	50	-	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

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	3a	3a x-a6	51	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	52	-	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	53	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	54	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	55	L	Monitoring Undertake monitoring of groundwater	LOW 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	56	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	57	-	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	58	-	Monitoring Undertake monitoring for presence of methane seepages in groundwater, including drinking water.	0	0	Quant	HH	Possible - low	-	-	-	-	-
Chemical Use	N/A	CSL5	CSL5	59	-	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	60	-	Traceability of chemicals used by an operator	0	0	Qual	LL	No	-	-	-	-	-
Chemical Use	N/A	CAL1	CAL1	61	-	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	62	-	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	63	-	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	64	-	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

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	CDL2	CDL2	65	-	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	66	-	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	67	-	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	68	-	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	69	-	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	70	-	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	71	-	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	72	-	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	73	-	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	74	-	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	75	-	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	76	-	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	77	-	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	78	-	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
Chemical Use	N/A	CSM1b	CSM1b	79	-	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	80	-	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

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	CSM1d	CSM1d	81	-	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	82	-	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	83	-	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	84	-	Select proppants which minimise the HVHF treatment required	0	0	Qual	MH	No	1	1	1	1	1
Chemical Use	N/A	CAH1	CAH1	85	-	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	86	-	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	87	-	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	88	-	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	89	-	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	90	-	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	91	-	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	92	-	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	93	-	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	94	-	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	95	-	Monitoring Water resources availability	0	0	Quant	MM	No	1	-	1	1	1

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

Categorisation		Measure info									Non-BAU, but Likely to be applied?	Policy Options				
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 ix	96	-	Monitoring Undertake monitoring of water volumes and origin	0	0	Quant	MM	No	1	-	1	1	1
Water Depletion	N/A	38d	38d	97	-	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	98	-	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	99	-	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	100	-	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	101	-	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	102	-	Spill kits available for use	0	0	Quant	MM	Yes	1	1	1	1	1
Surface Water	N/A	3a	3a ii	103	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	104	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	105	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	106	-	Berm around site boundary	0	0	Quant	HM	No	1	1	1	-	1
Surface Water	N/A	33g	33g	107	-	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	108	-	Bunding of fuel tanks	0	0	Quant	HH	No	1	-	1	-	1
Surface Water	N/A	30d	30d	109	-	Use of closed tanks for mud storage	0	0	Quant	HH	Possible - low	-	-	-	-	-
Surface Water	N/A	33b	33b	110	-	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	111	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	112	-	Impervious site liner under pad with puncture proof underlay	0	0	Quant	HH	Yes	1	-	1	1	1
Air Quality	N/A	59d	59d	113	-	Use of vehicles (water, chemicals, waste trucking) that meet minimum air emission standards e.g. EURO standards	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
Air Quality	N/A	N54	N54	114	-	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	115	-	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	116	-	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	117	-	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	118	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	119	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	120	-	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	121	-	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	122	-	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 emissions	Quant	MH	No	1	1	1	1	1
Air Quality	N/A	17b	17b	123	-	Reduced emission completions 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	124	-	Operator demonstrates availability of appropriate wastewater treatment facilities	0	0	Qual	LL	No	1	-	1	1	1
Waste	N/A	36c	36c	125	-	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	126	-	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	127	-	Lined open ponds with safety net protecting biodiversity	0	0	Qual	ML	No	1	1	1	1	1
Waste	N/A	27c	27c i	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	Treated wastewater	0	Qual	MM	Possible - high	-	1	1	1	1
Waste	N/A	3b	3b xiii	129	-	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	130	-	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	131	-	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	132	-	Consider wastewaters from unconventional gas operations as hazardous waste	0	0	Qual	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
Waste	N/A	N51	N51	133	-	Consider wastewaters hazardous unless operator demonstrates otherwise	0	0	Qual	MH	No	1	-	1	-	1
Waste	N/A	N52	N52	134	-	Ban injection of wastewaters into geological formations for disposal	0	0	Qual	MH	No	-	-	-	-	-
Waste	N/A	30c	30c	135	-	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 farmed, hauled off or injected down-hole.	Quant	HH	Possible - high	1	1	1	-	1
Post Closure	N/A	N22	N22	136	-	Maintain records of well location and depth indefinitely	0	0	Qual	LL	Yes	1	1	1	1	1
Post Closure	N/A	N11	N11	137	-	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	138	-	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	139	-	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	140	-	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	141	-	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	142	-	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	143	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

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
Post Closure	N/A	13d	13d iv	144	-	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	145	-	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	146	-	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	147	-	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	148	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	149	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	150	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	151	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	152	-	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 cement to remain in ground.	Quant	HH	Possible - high	1	1	1	1	1
Post Closure	N/A	13b	13b i	153	-	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 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
Post Closure	N/A	13b	13b ii	154	-	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	155	-	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 well.	Qual	HH	No	-	-	-	1	1
Public Acceptance	N/A	N23	N23	156	-	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	15ii	157	L	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) 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	158	-	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	159	-	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	160	-	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	161	H	Public consultation and engagement by operators: (i) at all stages (pre-permitting, permitting, exploration, testing, production and abandonment); (ii) 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	162	-	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	163	-	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	164	-	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

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	permit	N35	N35	165	-	Member States implement integrated permitting for unconventional gas	0	0	Qual	LL	No	-	1	1	1	1
Other Measures	N/A	N25	N25	166	-	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	167	-	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	168	-	Maintain operator liability for any pollution arising from wells indefinitely	0	0	Qual	LM	No	1	-	1	-	1
Other Measures	operator	N28	N28	169	-	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	170	-	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	171	-	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	172	-	Operators work together to ensure efficient provision of gas collection and wastewater treatment infrastructure	0	0	Qual	LM	No	-	-	-	-	-
Other Measures	ecology	N21	N21	173	-	Implement precautions to prevent invasive species by cleaning vehicles	0	0	Qual	ML	No	-	-	-	-	-
Other Measures	permit	N15	N15	174	-	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	175	-	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	176	-	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	177	-	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	178	-	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	179	-	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	180	-	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	181	-	Site selection close to water sources to minimise haulage requirements	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	trans	61b	61b i	182	-	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	183	-	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	184	-	Site selection close to wastewater treatment / disposal facilities to minimise haulage requirements	0	0	Qual	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
Other Measures	incident	N09	N09	185	-	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	186	-	Maximum noise levels specified	0	0	Qual	MM	Possible - high	-	-	-	-	-
Other Measures	noi	51c	51c	187	-	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	188	-	Operational hours specified	0	(Noise abatement)	Qual	MM	Possible - low	1	-	1	-	1
Other Measures	noi	51e	51e	189	-	Vehicle routes specified	0	(Noise abatement)	Qual	MM	Possible - high	1	-	1	-	1
Other Measures	noi	51f	51f	190	-	Machinery orientation and selection to minimise noise	0	(Noise abatement)	Qual	MM	Possible - low	1	-	1	-	1
Other Measures	noi	3a	3a viii	191	-	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	192	-	Monitoring Undertake monitoring of noise	0	0	Quant	MM	Possible - low	1	-	1	-	1
Other Measures	monitor	N27	N27	193	-	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	194	-	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	195	-	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	196	-	Competent Authorities have available sufficient inspection capacity and appropriately skilled inspectors	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	inspection	N33	N33	197	-	Independent inspection during all stages of development of well integrity	0	0	Qual	MM	No	-	-	-	1	1
Other Measures	ecology	N37	N37	198	-	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	199	-	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	trans	3a	3a v	200	-	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	201	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	202	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	203	-	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	204	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

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 xii	205	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	206	-	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	207	-	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	208	-	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	209	-	Monitoring Undertake monitoring of energy source and use	0	0	Quant	MM	No	1	-	1	-	1
Other Measures	monitor	3b	3b xii	210	-	Monitoring Undertake monitoring of greenhouse gas emissions	0	0	Quant	MM	No	-	-	-	1	1
Other Measures	ecology	3b	3b xvi	211	-	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	212	-	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	213	-	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	214	-	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	215	-	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	216	-	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 such an assessment without undue delay.	0	0	Quant	MM	No	-	-	-	1	1
Other Measures	equip	N18	N18	217	-	Ensure equipment is compatible with composition of fracturing chemicals	0	0	Qual	MM	Possible - high	1	-	1	-	1
Other Measures	equip	N19	N19	218	-	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	219	-	Environmental management system accreditation for unconventional gas installation operators	0	0	Quant	MM	No	1	-	1	-	1
Other Measures	materials	30e	30e	220	-	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	221	-	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	222	-	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

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	incident	9b	9b	223	-	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	224	-	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	225	-	Use of temporary surface pipes for distribution of water supply	0	Temporary pipes laid above ground to supply water to pads.	Qual	HH	No	1	1	1	-	1
Other Measures	trans	60b	60b	226	-	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	1	1	1	-	1
Other Measures	trans	61a	61a	227	-	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