FracRisk

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Deliverable summary text:
Legislation and regulatory practices of those member states with significant shale-gas reserves (United Kingdom, France, Germany, Spain, Poland, Austria, Hungary and Romania) will be collated and compared with each other, and with legislation from some of the other first-world countries with mature shale-gas industries. The main focus of the collation and review will be on how existing legislation recognizes and seeks to control risks arising from uncertainties embedded in the shale-gas industry's exploration and exploitation practices. The legislative review undertaken as part of this project will take on board the findings of the periodic Section 16 reviews, planned in the Commission Recommendations of 22 January 2014 on minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high-volume hydraulic fracturing. Therefore, the review will necessarily have to be continually updated throughout the life of the project.

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H2020 - Project FracRisk: Interim Legislative and Regulatory Review - Summary of Legislation and Regulation relating to Onshore Hydraulic Fracturing for Shale Gas in the EU

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1 Introduction

1.1 Background

This report is provided as part the research project "FracRisk" (filed as Cordis Project ID 636811) "Furthering the Knowledge Base For Reducing the Environmental Footprint of Shale Gas Development".

Project FracRisk was commissioned as part of LCE-16-2014 - "Understanding, preventing and mitigating the potential environmental impacts and risks of shale gas exploration and exploitation" and is funded by the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No. 640979.

1.2 Purpose and scope of this report

This report constitutes a deliverable (D7.2) under the FracRisk Work Package 7 (*Dissemination: scientific recommendations for Best Practices, Knowledge base and Legislative Review*) and is *inter alia* intended to establish an outline of the current EU and member state legislative and regulatory framework regarding environmental protection associated with shale gas development.

This report is an interim review, coming half way through the programme of the project, and is the first of three (a Final Legislative Review and a Policy and Legislative Recommendation are scheduled to be released towards the end of the project). Its purpose is to bring real world context to help focus the FracRisk's scientific output so that it can achieve maximum impact and utility. As such, its intended audience is both external to the project (for information) as well as internal (to assist project direction).

The main focus of this review is on how existing legislation recognizes and seeks to control risks arising from scientific uncertainty embedded in the shale-gas industry's exploration and exploitation practices - specifically to those practices that relate to the research associated with the science of the FracRisk project.

The report also summarises the findings from a number of legal and risk management research projects commissioned and funded by the EU over the last five years which examine the scope for any legislative intervention to regulate upstream activities associated with onshore exploration and exploitation of unconventional fossil fuels. The risk assessment and management approaches established in these series of reports will be compared and contrasted with the risk management approach taken by the FracRisk project.

Necessarily, as the report is addressed in part to members of the scientific community, and is intended to help these members direct their research towards a utilitarian end, the principles governing EU legislation are set out and explained before the legislation is summarised. The report therefore starts from first legal principles and in this respect it will differ from other EU funded research projects which assume an audience which is legally trained.

1.3 Project FracRisk

The FracRisk project was funded to further develop the understanding of the hazard and risk associated with the upstream exploration and exploitation of onshore shale gas reserves found throughout Europe, and to further develop the knowledge of state of the art prevention and mitigation techniques.

The project scope is to investigate the science associated with issues related to, and consequent upon, the process of hydrofracking of rock. Specifically it is to investigate induced seismicity, and the migration of fracture fluids and liberated gasses through zones of both undisturbed and purposefully fractured rock. Of six main mechanisms of gas and fluid release (see list below), the project expressly excluded three that related to risks associated with flows stemming from surface spills and leaky wells.

Fracking Fluid Flow:

- F1: Flow through natural or artificially created fractures or abandoned well: The fracking fluid could be forced through a fracture (or fault) or incorrectly abandoned well as a result of the strong pressure build up in the system. This pressure build up diminishes as soon as the fracking operations (which may last about 2h) are stopped, and the flow ceases.
- F2: (not addressed by FracRisk) Flow through leaky borehole (well integrity problem): Fluids may leak into the freshwater aquifer through the borehole (e.g., due to a faulty installation). However, this would imply an incomplete sealing of the borehole annulus or the use of leaky cement.
- F3: (not addressed by FracRisk) Spill at the ground surface: In the case of an accident, large amounts of contaminants may infiltrate into the aquifer. A continuous contamination of the aquifer is also possible if a leak occurs undetected.

Methane Gas Migration:

- M1: Flow through natural or artificially created fractures or abandoned well: Due to the large difference in density, the upward flow of methane continues as long as free-phase methane is present.
- M2: (not addressed by FracRisk) Flow through leaky production well.
- M3: Methane flow through the rock: Some amount of methane which is mobilized during the fracking process may escape from the reservoir through the fractures. This methane would no longer be trapped by adsorption or low permeability and would rise due to buoyancy.

Project FracRisk is classified as a geoscience project. The research programme was planned to address the risks associated with seismicity and migration mechanisms (F1, M1 and M3) as follows:

- Assessment of the environmental impact from induced seismic activity and from the release of substances into the environment during the exploration and exploitation phases of onshore shale gas production based on the understanding of the geophysical, subsurface

flow and transport processes involved, the available geological, hydrogeological and geophysical data and appropriate source term and boundary conditions;

- Forward modelling with mathematical models to predict the effect of migration of chemicals and gases, and the mechanical effects (seismics), together with risk and uncertainty quantification/assessment based on six focused exemplary scenarios (before, during and after fracking operations) to direct cost effective data gathering;
- Develop and test a framework for risk assessment to be used both by regulators and contractors, based on the well-known ASTM RBCA (Risk Based Corrective Action) paradigm.
- Development of criteria for appropriate monitoring strategies to measure baseline conditions, as a pre-warning system and to validate mathematical models and concepts;
- Provision of scientific recommendations and a knowledge base for best practices for shale gas development and with direct application and relevance to the provision of consistent regulation.

1.4 Application and utility

Within the general scheme of upstream shale gas activity, the FracRisk project is not concerned with evaluation of the geology for its potential as a shale gas reserve; rather its science is most readily applicable to the evaluation of hazard and risk due to the placement of a shale gas well into a particular geological and environmental setting. FracRisk science therefore finds its natural application within an Environmental Impact Assessment or similar process during the permitting stage prior to well drilling. The timeframe over which these hazards and risks are evaluated run from the first fracking stage, through the gas production stage, to well closure and post abandonment stage.

Detailed consideration of the EU and Member State law in this review is therefore focused on how current regulations reflect the uncertainties in the science relating to these fracking activities (induced seismicity and fluid and gas migration) and use this understanding to deliver fair and robust governance.

Notwithstanding this very narrow focus, an overview of the whole regulatory regime relating to shale gas will be summarised within this review in Chapters 4 and 5, as it provides the necessary context for the more focused detailed consideration in Chapter 6.

2 Summary of EU research relating to shale gas and hydrofracking

2.1 EU funded research and policy development

The EU commenced research into the technical and legal aspects of shale gas hydrofracking in 2010 when it became apparent that the environmental aquis did not address certain issues arising from the novel techniques that were likely to be employed in any onshore upstream shale gas industry in Europe. The European Commission's research was to facilitate effective policy development in this emerging sector to find the balance between protection and regulation.

The scientific and the legal research that has been funded by the European Commission has been consulted and used to compile this interim review.

2.2 Commission funded research into legislation and regulation

Table A below lists and briefly summarises the extent and nature of a series of projects' research into the areas of legislation at EU and national levels, including the regulatory regimes that existed at the time the reports were written. Extensive review of all parts of the environmental aquis have been examined and analysed, and this literature is effectively current up to the February 2015 when the Milieu & Ricardo report on the implementation of Recommendation 2014/70/EU was released. Taken together these reviews constitute a broad and deep body of knowledge on EU and member states regulation of critical aspects of environmental legislation within the EU as it pertains to shale gas and other unconventional hydrocarbon (UH) fracking. This review relies heavily on this research.

2.3 Commission funded research into fracking science and risk

Table B below lists the technical research projects that have been commissioned, which include overlaps with parts of the FracRisk project in the areas of risk assessment and best practices for criteria for baseline data gathering and monitoring strategies.

2.4 H2020 funded research projects

The H2020 programme is currently funding three sister shale gas related science research projects; and there is liaison between the science teams. However, the interim finding of these projects have not consulted for the purposes of this report and they are listed below for the sake of completeness:

- ShaleXenvironmenT - Maximizing the EU shale gas potential by minimizing its environmental footprint ID: 640979 - Start date: 2015-09-01 - End date: 2018-08-31
- SHEER - SHale gas Exploration and Exploitation induced Risks ID: 640896 - Start date: 2015-05-01 - End date: 2018-04-30
- M4ShaleGas - M4ShaleGas: Measuring, monitoring, mitigating managing the environmental impact of shale gas ID: 640715 - Start date: 2015-06-01 - End date: 2017-11

2.5 Hydrocarbons BREF

A working group to research and provide input to this BREF was established in mid 2015 with the aim of providing a forum for the sharing of Best Available Techniques (BAT) to "*manage impacts of releases of pollutants and best risk management techniques to manage risks of releases of substances as a result of incidents for the purpose of protecting human health and the environment.*"

Whilst these best practices have no legal effect they establish an Europe wide set of objective standards against which operators can be held to account in the event of questions of fault based negligence liability.

Table A - Summary of EU funded shale gas legislative and regulatory research

Dates	Author	Title (with hyperlink to document)	EU Summary	Legal / Technical Outcomes	Relationship to FracRisk
February 2016	Milieu & Ricardo	Study on the application in 11 Member States of the Recommendation 2014/70/EU on minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high-volume hydraulic fracturing Country reports Stakeholders' consultation	This study assesses how Member States applied the principles of the Recommendation and selected EU legal requirements at the planning, licensing and permitting levels based on data collected from January 2014 to August 2015. In addition, it describes regulatory and non-regulatory developments in Member States after the adoption of the Recommendation and gathers stakeholders' views.	Investigation of the EU environmental aquis and its application as transposed legislation and regulation within Austria, Denmark, Germany, Hungary, Lithuania, Netherlands, Poland, Portugal, Romania, Spain, UK.	Directly applicable to this legislative review - see chapter 5 below for summary of its findings
July 2013	Milieu	Study on the regulatory provisions governing key aspects of unconventional gas development in eight Member States Country Reports	The main objective of this study was to identify differences and commonalities in the approaches to the development of gas from unconventional reservoirs followed by the selected Member States and to examine the potential limitations and useful examples of regulatory provisions. This study was conducted on the basis of information collected between October 2012 and April 2013. Country reports are presented as separate documents.	Investigation of the EU environmental aquis and its application as transposed legislation and regulation within Bulgaria, Denmark, Germany, Lithuania, Poland, Romania, Spain, UK.	Directly applicable to this legislative review - see chapter 5 below for summary of its findings
August 2012	AEA (now trading as Ricardo Energy and Environment)	Potential risks for the environment and human health arising from shale gas extraction in Europe	The main objective of this study was to assess the risks of surface and ground water contamination, water resource depletion, air and noise emissions, land take, disturbance to biodiversity and impacts related to traffic are deemed to be high in the case of multiple projects; and to undertake a gap analysis of legislation and regulation. were identified. *(The study was re-issued on 11 February 2013 with minor corrections in the preliminary risk screening)*.	A review of the effectiveness of EU legislation and a gap analysis of the main aspects of the EU environmental aquis was completed, and it was concluded that there was need for an appropriate risk management framework to ensure an environmentally acceptable shale gas extraction industry in Europe.	Directly applicable to this legislative review - see chapter 4 below
November 2011	Philippe & Partners	Final Report on Unconventional Gas in Europe in the framework of the multiple framework service contract for legal assistance	The main purpose of the Study is to analyse how the relevant applicable European legal framework, including environmental law, is applied to the licensing/authorisation and operational permitting for prospection, exploration and production/exploitation of shale gas based on a sample of four Member States.	Investigation of the EU environmental aquis and its application as transposed legislation and regulation within Germany, France, Poland and Sweden.	Directly applicable to this legislative review - see chapter 5 below for summary of its findings
January 2012	European Commission	Commission services guidance on the main EU environmental legislation applicable to unconventional hydrocarbons projects involving the use of high volume hydraulic fracturing, 2012	This transmission note briefed the EU Parliament and the public on the EU Commissions interpretation of EU legislation relating to shale gas projects.	Covers the issues applicable to shale gas under eight EU Directives/Regulations.	Directly applicable to this legislative review - see chapter 4 below
December 2011	European Commission	Commission services guidance on the application of the Environmental Impact Assessment Directive (2011/92/EU codified) to projects related to the exploration and exploitation of unconventional hydrocarbons, 2011	This guidance note explained how the EU Commission believed a competently implemented EIA under the Directive would be carried out for projects with hydraulically fractured horizontal wells for shale gas.	Highlights the responsibility of member states to employ a proper screening processes (including use of the precautionary principle and prevention principle) in the event a shale gas project is not captured under the ambit of Annex I of the directive.	Directly applicable to this legislative review - see chapter 4 below

Table B - Summary of EU funded shale gas and other UH related science research

Dates		Title (with hyperlink to document)	EU Summary	Legal / Technical Outcomes	Relationship to FracRisk
November 2016	European Commission	The European Commission organised in Brussels a "Technical workshop on public health impacts and risks resulting from the exploration and production of hydrocarbons".	A series of state of the art progress summaries as provided as MS PowerPoint presentations	Summary of latest thinking in this field	Applicable to FracRisk science in that the Features Events Processes (FEP) risk methodology developed by FracRisk seeks inter alia to quantify human health impact due to exposure to fracking geohazards.
October 2016	AMEC Foster Wheeler	Study on the management of environmental impacts and risks of conventional oil and gas (onshore and offshore) and tight gas (offshore) extraction	This report assesses the environmental risks, impacts and risk management measures associated with the conventional exploration and production of hydrocarbons in the EU. It also covers processes and technologies associated with offshore tight gas activities.	[Report Abstract]: The report assesses the environmental risks, impacts and risk management measures associated with the conventional exploration and production of hydrocarbons within Europe. It also covers processes and technologies associated with offshore unconventional activities. The study used a lifecycle approach to break down exploration and production of hydrocarbons into five stages following a similar approach used for previous studies for the European Commission. Sub-stages and processes were then identified for each life-cycle stage for both offshore and onshore. For each process and sub-stage the environmental risks were assessed based on 8 environmental aspects (e.g. noise) for offshore and 10 for onshore. To conduct this assessment the risks and impacts of each aspect were reviewed against a risk rating system, based on consequence and likelihood. The assessment was conducted using a combination of data gathered from the oil and gas industry, including environmental impact assessments/statements, and expert judgement. The impacts of management measures on risks were also assessed. Finally, the risks and impacts identified for onshore unconventional exploration and production from a preceding study were compared to the risks and impacts of offshore conventional exploration and production in this study to determine the environmental risks of offshore unconventional's at sea.	Directly applicable to the regulatory review process within FracRisk of which this legislative review is the first stage, and complimentary to the FracRisk risk assessment and management methodology as research into the science of quantitative geohazard risk assessment provided by the FracRisk project feeds into and strengthens this broader research effort.
August 2015	AMEC Foster Wheeler	Technical Support for the Risk Management of Unconventional Hydrocarbon Extraction - Final Report	This report compliments the technical report of August 2014 by AMEC and Philippe & Partners and examines the options for legislative reform to cover other forms of unconventional hydrocarbon extraction other than that from shale gas. The same risk methodologies and methods for establishing compliance costing are employed.	Extended the ambit of the August 2014 report to include risk assessment and costed risk mitigation measures for other unconventional hydrocarbons other than HVHF shale gas plays. Some 230 non-BAU measures/sub-measures were identified.	Directly applicable to the regulatory review process within FracRisk of which this legislative review is the first stage, and complimentary to the FracRisk risk assessment and management methodology.
August 2014	AMEC and Philippe & Partners	Technical Support for Assessing the Need for a Risk Management Framework for Unconventional Gas Extraction - Final Report	This 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 study undertook a regulatory and technical analysis to summarise key risks and hazards, building on work conducted by AEA August 2012; identified suitable measures to manage such risks; provided support the development of policy options, in discussion with the Commission, to manage risks; completed an impact assessment by providing 'building blocks' supporting an Impact Assessment of the selected policy options in line with the Commission's Impact Assessment Guidelines; and provided support for the development of a risk management framework though technical or legal support to the development of a defined risk management framework. By using the example of a generic "Illustrative Concession", and using the concept of non-BAU measures developed in the ICF 2014 report, risk mitigation measures were costed for four different policy options at different levels of implementation "ambition". Over 200 potential non-BAU measures were identified.	Directly applicable to the regulatory review process within FracRisk of which this legislative review is the first stage, and complimentary to the FracRisk risk assessment and management methodology.
2013 - released 2015 - updated	JCR Science Hub	Overview of hydraulic fracturing and other formation stimulation technologies for shale gas production	This study reviews hydraulic fracturing and alternative fracturing technologies, by searching the open literature, patent databases and commercial websites. Each identified technique is briefly explained, its rationale, state of application, potential advantages and disadvantages are identified, and some considerations on costs are given. It was updated in 2015.	Technical data	Provides technical data for use in FracRisk science

Dates		Title (with hyperlink to document)	EU Summary	Legal / Technical Outcomes	Relationship to FracRisk
April 2014	ICF International	Mitigation of climate impacts of possible future shale gas extraction in the EU: available technologies, best practices and options for policy makers	[Abstract] - The specific objectives of the study were to: Analyse international experiences in minimising on-site fugitive GHG emissions during exploration and production of shale gas, identifying lessons and best regulatory practices that could be used in the EU. Analyse shale gas exploration and production technologies and practices to provide an overview of the most advanced technologies and practices that could be promoted or enforced for minimizing on-site fugitive GHG emissions. Develop and provide an overview of different policy options for a possible regulatory framework for minimizing on-site fugitive GHG emissions and promoting the most advanced technologies and practices of shale gas exploration and production. This task aims to provide an overview of the different options for a regulatory framework, and an assessment of these options based on a common set of criteria to identify 3 or 4 to assess in the next task. Analyse the climate, environmental, social and economic impacts of relevant policy options.	Various impacts were analysed in accordance with the European Commission's guidance on impact assessment (January 2009), and associated guidance including the "Competitiveness Proofing" Toolkit, and were compared to a base case or 'business as usual' (BAU) scenario that assumed no additional regulations for minimising on-site fugitive GHG emissions. Sate of the art technologies and practices of shale gas exploration and production beyond those already in place or planned at an EU or Member State level were analysed.	Provides valuable data and context on approaches to evaluating shale gas project environmental risk and its regulation albeit in an technical area that is not the specific research concern of FracRisk.
January 2013	European Commission Joint Research Centre	Study on the assessment of land and water use scenarios for shale gas development: Poland and Germany	This study focuses on pressures on freshwater resources and land use competition with respect to shale gas development in illustrative case studies in Germany and Poland.	Technical data	Provides technical data for use in FracRisk science
September 2013	European Commission Joint Research Centre	Assessment of the use of certain substances in hydraulic fracturing of shale gas reservoirs under REACH	This study assesses a number of REACH registration dossiers related to 16 substances that may be used for hydraulic fracturing of shale gas reservoirs.	Technical data	Provides technical data for use in FracRisk science

3 Shale gas and hydraulic fracturing

3.1 Shale Gas

The nature of hydrocarbon deposits including those of shale gas is extensively set out and discussed in the EU funded project by AEA 2012-08 and AMEC 2015-08. What follows is a brief summary from these reports.

Shale gas is found within sedimentary organic-rich rock formed from deposits of silt, clay, and organic matter, where the gas has formed by the biogenic production of gas by anaerobic micro-organisms at low temperatures and/or by thermogenic production of gas at higher temperatures and pressures at greater depth.

Shale gas deposits can be continuous over areas of thousands of square kilometres, and are typically located deep (>1000m) within the subsurface.

Shale gas deposits are an "unconventional" form of hydrocarbon deposit; a term which is also applied to tight gas, tight oil and coal bed methane. Typical abbreviations used are Unconventional Fossil Fuels (UFF) or Unconventional Hydrocarbons (UH), which are contrasted with Conventional Fossil Fuels or Hydrocarbon Deposits (often abbreviated as CFF or CH respectively). The origin of the term ‘unconventional’ derived from the use of hitherto rarely used techniques such as horizontal drilling and high volume hydraulic fracturing to recover the gas or oil; though nowadays such operations are routinely used on CFF resources as well.

The most evident differences between CFF reservoirs and UFF shale gas reservoirs are:

- there is gas/oil migration from a source rock (CFF) versus gas remaining within the source rock (shale gas)
- in CFF a cap rock is configured to trap the migrating oil/gas underground (this is not necessary for shale gas which remains in situ in the source rock)
- CFF reservoirs have significantly greater permeability than shale gas deposits (10-1 to 10-4 millidarcy (md) compared to 10-5 to 5.0x10-4 md). The low permeabilities of the shales require artificially fracturing (hydrofracturing or "fracking") to facilitate extraction of the gas.

AMEC 2015-08 summarised and compared the salient features and characteristics of upstream UFF and CF plays into a convenient matrix (ref: Table 2.1 AMEC 2015-08) and this matrix is reproduced as Table C below.

Table C - Comparison of CFF and UFF characteristics (reproduced from Table 2.1 of AMEC 2015-08)

Criteria		CFF	UFF			
Main	**Secondary**		**Shale Gas**	**Tight Gas**	**Tight Oil**	**Coal Bed Methane**
Gas and oil flow to a well without stimulation or enhanced recovery		Yes although some stimulation/enhanced recovery may be required to maximise recovery	No	No	No	No
Areal extent of a play		Oil and gas fields usually occur in defined structural or stratigraphic traps that cover less than the full area of the reservoir, formation or play. Typically small surface area in Europe e.g. Wytch Farm, UK has a mapped surface area of <100 km^2	Can extend up to a large extent of the formation, which can be large e.g. 250,000 km2 for the Marcellus Shale in the US. Many European prospects have areas >1,000 km^2	Extensive in the US. Potentially large areas in Europe (Germany, Hungary) but limited information	Extensive in US Limited information on plays in Europe. Potential deposits in Europe (27 plays identified by IHS CERA, 2013)	Can extend over large area up to the full extent of the coal. Large areas of coal in Europe but limited information on CBM potential.
Recovery factor (% resource recovered)		High (40 to 80%). Oil being at the low end and gas at the high end.	15 to 35%	10%	1 to 22%	High (50 to 90%)
Reservoir rock geology		Sandstones Carbonates	Shale	Sandstones Carbonates	Siltstones, sandstones carbonates or shale	Coal
Reservoir rock structure		Oil and gas found in traps created by geological structures (e.g. antiforms, faults, salt diapirs)	Occurrence not related to traps	Occurrence not always related to traps	Occurrence not always related to traps	Occurrence not related to traps
Reservoir rock permeability		Various definitions: more than 0.1 mD 'high' permeability	Various definitions: less than 0.1 mD 'low' permeability	Various definitions: less than 0.1 mD 'low' permeability	Various definitions: less than 0.1 mD 'low' permeability	Variable
Reservoir rock thickness		Highly variable as it depends on the nature of the trap	Highly variable (e.g. 6 to 610 m for US shales up to 900 m in UK in deep basins)	Highly variable	Highly variable	Typically thin (<10 m)
Depth		Highly variable but increasingly deep 1,800 to 5,500 m	Variable (e.g. 180 to 4,000 m for US shales 1,800 to 4,200 m)	Typically deep (e.g. 3,500 to 5,000 m in Cloppenberg Germany 1,800 to 4,200 m)	Typically deep (e.g. 600 to 2,900 m in Canada 1,200 to 3,600 m)	Typically shallow ~e.g. 800 m in Falkirk; 1,000 m in Munsterlander Becker Region, Germany, 600 to 1100, 500 to 1,500 m)
Drilling Methods		Standard	Standard	Standard	Standard	Standard
No. of wells per field		Typically few wells used but number increased when enhanced recovery techniques used. (e.g. Schoonebeeke in the Netherlands required 73 new wells for steam injection (E.g. Wytch Farm – Europe's largest onshore CFF oil field has approximately 100 wells at 13 sites including injection and recovery wells).	Large numbers (e.g. 200 to 800 proposed for NW England)	Large (e.g. 300 wells for tight gas in Germany)	Potentially large e.g. in Bakken of North Dakota between 122 and 189 drilling rigs were active (2010 to 2014) NDIC website access 02 June 2014	Current schemes in Europe are small e.g. 20 wells in Falkirk but schemes in the US have a typical size of 70 wells and the number of wells per basin exceeds 1000
Use of horizontal wells		Not always used	Generally used	Generally used	Generally used	Commonly but not always used. Falkirk scheme proposes the use of horizontal wells (L)
Length of horizontal portion of well (lateral)		Variable e.g. up to 4800m at Wytch Farm	900 to 3,000 m	30 to 5,750 m	800 to 4,500 m	300 to 1,200 m
Multi-well pads		Variable use. May be used onshore to reduce footprint (e.g. Wytch Farm in the UK)	Typical in US. Multi -well pads planned for Europe	Typical in US - 14 wells per pad	Typical	Dependant on the technique and well configuration used to extract gas (e.g. 4 indicated)
Pad separation		Large to avoid interference	1 to 5 km	1 to 5 km	1 to 5 km	Close to create interference
Well density		1 well per 10 km^2	1 well per 1 km^2	1 well per 1 km^2	1 well per 1 km^2	1 well per 0.16 to 0.32 km^2

Criteria		CFF	UFF			
Main	**Secondary**		**Shale Gas**	**Tight Gas**	**Tight Oil**	**Coal Bed Methane**
Stimulation by hydraulic fracturing	Utility of Hydraulic fracturing	May be used	Required	Required	Required	Not always used
	Volume of water used per well per fracture	0.0 to 700 m^3	7,600 to 34,100 m^3	100 to 12,000 m^3	500 to 25,600 m^3	0.0 to 4,700 m^3
	Injection pressure at reservoir	Depends on pressure regime / depth 828 bar	Depends on pressure regime / depth 690 bar	Depends on pressure regime / depth 690 bar	Depends on pressure regime / depth 552 bar	Depends on pressure regime / depth 207 bar
	Use of additives	Required	Required	Required	Required	Not always used
	Use of proppants	Not always required	Required	Required	Required	Not always used
	Flowback volume	30%	50%	17% to 35%	10 to 60%	61 to 82%
	Cavitation	No information	No information	No information	No information	Used to increase permeability of wells in thick coal seams
Enhanced recovery techniques used		Gas injection (carbon dioxide, natural gas). Natural gas used in Europe but not carbon dioxide. Carbon dioxide has been used extensively in the US due to availability of natural carbon dioxide. Water flooding (widely practised in Europe Chemical flooding Heat (steam) injection (used at Schoonebeeke, NL). Use is highly variable –and increases with time	No evidence of use CO2 injection at experimental stage. Use is variable and decreases with time and rate of gas production	No evidence of use. Use is variable and decreases with time and rate of gas production	No evidence of use	Lowering of hydrostatic pressure required. Use is high and decreases with time CO2 injection (technology at early stage of development)
Wastewater – produced water	Presence of naturally occurring radioactive materials (NORM)	Presence is formation specific	NORM typically present	Presence is formation specific	Presence is formation specific	Presence is formation specific
	Salinity of water	1,000 to 400 000 mg/l salinity	5,000 to 200,000 ppm		211 to 107,000 mg/l as chloride	1 to 128,000 mg/l as chloride
	Disposal routes (North America = "NA")	Treatment and deep injection in NA (to enhance recovery). Treatment and discharge to coastal waters (e.g. North Sea)	Treatment and deep injection in NA. Treatment and discharge to inland waters in NA	Treatment and deep injection (e.g. Germany)		Treatment and deep injection in NA Treatment and discharge to coastal waters (e.g. proposed by Dart Energy, in UK). Treatment and discharge to inland waters

3.2 High volume hydraulic fracturing (HVHF)

Hydrofracking is a form of well stimulation. Well stimulation is treatment to the rock formation and can be undertaken at either below formation fracturing pressure (matrix treatment) or at above formation fracturing pressure (hydraulic fracturing) in order to improve recovery of a hydrocarbon from the reservoir. Matrix treatments are used on CH and UH wells for improvement of permeabilities close to the wellbore.

Hydraulic fracturing is achieved by injection of a liquid under pressure via the wellbore to induce fractures in the surrounding rock. The liquid "fracking fluid" consists of a finely adjusted mixture of mud's and chemicals and contains a "proppant" to keep the factures open to permit flow of gas through the formation to the well.

High volume hydraulic fracturing (HVHF) is a term used within the oil and gas industry to denote hydrofracking that employs "significant" volumes of fracking fluid within a well; though the volume of fluid used in the definition is arbitrary:

- 380 m^3 per well - Michigan Department of Environmental Quality
- 1,140 m^3 per well - New York Department of Environmental Conservation
- 1,000 m^3 per fracturing stage or 10,000 m^3 or more of water during the entire fracturing process into a well - EU Recommendation 2014/70/EC (N.B. - this is a non-legally-binding EU wide definition that has been adopted within some member states as a legal definition - e.g. UK Infrastructure Act 2015)

For shale gas recovery, the fracturing is undertaken within horizontal wells in stages over intervals of the horizontal wellbore. The process generally breaks down into a sequence of activities, where intervals of the horizontal wellbore are packered-off and isolated and the casing is perforated; the wellbore is flushed with clean water and then an acid flush is introduced to dissolve cement adjacent to the perforations. Water is injected and "shut in" and formation response is gathered, fracture fluid without proppant is injected, and finally proppant is injected

3.3 Overview of stages of upstream activity for shale gas

A shale gas well play will typically be operated in distinct phases. Typically these might be (per AEA 2012-08):

- site preparation - clearing and levelling an area of adequate size and preparing the surface to support movement of heavy equipment plus design and construction of access routes;
- well design and construction - drilling, casing, cementing and perforation. Typically this consists of drilling casing and cementing the conductor hole at the ground surface. A vertical pipe is set into the hole and grouted into place. The second drilling stage is to drill the remainder of the vertical hole. Surface and intermediate casings are constructed, cemented and horizontal bores drilled. The pipework and cement is then perforated, and the wellhead constructed;

- hydraulic fracturing - where water with proppant (typically sand) and chemicals is pumped into the well at high pressure;
- well completion and wastewater management - were flowback and produced water is managed;
- production - produced water is separated from the gas and disposed of; and gas is recovered and sold;
- decommissioning and then abandonment.

4 Overview of EU legislation relevant to upstream onshore shale gas production

4.1 Introduction

This chapter constitutes a brief overview of EU legal principle for researchers engaged in scientific research into shale gas and hydrofracking; and includes a broad review of some of the salient elements of the EU law relevant to this industry. The next chapter (chapter 5) builds from this chapter and covers the member states implementation of this law into their national laws and regulations.

4.2 Basis, nature and principles of the EU "environmental aquis"

The accumulated legislation, legal acts, and court decisions which constitute the body of EU law is customarily referred to as the "acquis communautaire". The "environmental aquis" is that part of the " acquis communautaire " that pertains specifically to the environment.

Two extant treaties currently constitute the constitutional basis of the EU's existence and the nature and extent of its powers and jurisdiction. These are the Treaty on European Union (TEU), which was created by the Treaty of Lisbon in 2007 which effectively amended and transformed the Maastricht Treaty of 1993; and the Treaty on the Functioning of the European Union (TFEU), which was likewise created by the Lisbon Treaty by the amendment of the Treaty of Rome of 1957.

These treaties provide numerous powers to the EU including the power to make laws that bind the member states; which in effect amounts to a loss of part of each member states sovereignty. EU binding legislation can take three forms:

- Regulations - laws are "directly applicable" within member states without the need for member states transposing them into national law; and with provisions that can have "direct effect" (see below);
- Directives - are laws that are addressed to and which require all member states to give effect to their provisions by transposing them into national legislation; and
- Decisions - which are addressed to specific member states, companies or individuals, and which are binding on them.

The EU can also issue non-binding Recommendations that are intended to act as persuasive guidance on behaviours and regulation within the member states. These are typically used where the EU feels it is not sufficiently appraised of the facts and technical understanding of a sector in which, in the future, it may wish to step in and legislate. Recommendation 2014/70/EU relating to shale gas and HVHF is such an instrument.

Regulations, Directives and Decisions are constrained in the way they bind government, companies and individuals, and how they allow legal persons (including regulators) to use these laws. Where obligations within a provision are clear and unambiguous, unconditional, and independent of the

need for any further EU or member state government action, then such obligations will have "direct effect". The extent of this direct effect can be "vertical" allowing an individual to invoke the obligation within a provision against the member state before a national court; and may also be "horizontal" which then allows an individual to invoke the obligation against another individual before a national court. Regulations and Decisions can have direct effect, but Directives cannot.

The powers conferred by these treaties are made subject to a number of fundamental guiding principles.

The overarching principles governing legislative intervention and lawmaking by the EU are as follows:

- "proportionality" - action of the EU shall not go beyond what is necessary to achieve the objectives of the treaties;
- "subsidiary" - decisions should be taken as closely as possible to the citizen;
- "margin of appreciation" - member states have some discretion in how to interpret EU policy;
- "devolution of competence" - some EU law can be given effect and administered by transposition into national, regional or local government laws and regulations.

Subordinate environment specific principles that have evolved or been enacted include:

- "polluter pays principle" - fault-based liability for operators or a competent authority requiring them to take necessary preventive and restorative measures for environmental damage, codified in the Environmental Liability Directive 2004/35/EC;
- "precautionary principle" per Article 191 of TEU empowering authorities responsible for risk management to invoke it when an action or process, as identified by a scientific and objective evaluation, if found to present a risk that cannot be evaluated with an acceptable level of certainty. Guidelines to the use of this principle were set out in the Communication from the Commission on the precautionary principle (COM(2000) 1 final. The precautionary principle may only be invoked when the three preliminary conditions are met, namely that there has been: identification of potentially adverse effects; evaluation of the scientific data available; and evaluation of the extent of scientific uncertainty. A number of principles must be employed when assessing these conditions: the "fullest possible scientific evaluation, the determination, as far as possible, of the degree of scientific uncertainty; a risk evaluation and an evaluation of the potential consequences of inaction; the participation of all interested parties in the study of precautionary measures, once the results of the scientific evaluation and/or the risk evaluation are available." Additionally five principles of risk management are invoked: "proportionality between the measures taken and the chosen level of protection; non-discrimination in application of the measures; consistency of the measures with similar measures already taken in similar situations or using similar approaches; examination of the benefits and costs of action or lack of action; review of the measures in the light of scientific developments."

- "preventive action" - concept that prevention is better than cure, requiring early assessment of environmental risks to identify environmental damage at source synergic with a "proximity principle" that holds that environmental damage is best rectified at source.

4.3 Legislation relevant to shale gas

In Annex 2 of the "EU Commission Transmission Note on the EU environmental framework applicable to shale gas projects" - eight main EU laws were identified as pivotal to the proper governance of the shale gas industry in the EU. Some of this legislation has subsequently been repealed or amended, and the current list of most relevant EU legislation relating to upstream shale gas activity is presented in Table D, along with the numbers (and hyperlinks to):

- modifications to the legislation
- decisions associated with the legislation
- legal cases some of which decide substantive points of law
- national legislation of the member states transposing the relevant EU directive

4.4 Gap analysis of EU legislation relevant to shale gas

The EU commissioned research in 2012 into the effectiveness of the environmental aquis as it related to shale gas and hydrofracking, and a gap analysis of 19 pieces of legislation relevant to all or some of the stages of shale gas resource development were identified and reviewed (see Table E below).

The review sought to identify the extent to which shale gas exploration and production risks were not covered under current EU legislation and to identify gaps or possible inadequacies in EU legislation which were then classified as [from AEA 2012-08]:

- *"Inadequacies in EU legislation that could lead to risks to the environment or human health not being sufficiently addressed.*
- *Potential inadequacies –uncertainties in the applicability of EU legislation: the potential for risks to be insufficiently addressed by EU legislation, where uncertainty arises because a lack of information regarding the characteristics of high volume hydraulic fracturing (HVHF) projects.*
- *Potential inadequacies –uncertainties in the existence of appropriate requirements at national level: aspects relying on a high degree of Member State decision-making for which it is not possible to conclude under this study whether or not at EU level the risks are adequately addressed."*

How these gaps in the EU legislation have allowed significant differences in member states behaviours and regulatory practices is discussed in the next chapter (Chapter 5).

Table D - EU level legislation governing critical aspects of environmental risk associated with shale gas hydrofracking (N.B. - all cells have a hyperlink to their relevant document or list of documents except those in the column "Title")

EU LEGISLATION					NATIONAL IMPLEMENTING LEGISLATION													
Instrument Name	**Title**	**Follow-on EU Instruments**	**DECISIONS**	**CASELAW Judgements**	**AUT**	**BGR**	**DNK**	**FRA**	**DEU**	**HUN**	**LTU**	**NLD**	**POL**	**PRT**	**ROU**	**ESP**	**SWE**	**GBR**
Directive 92/43/EEC	Council Directive 92/43/EEC of 21 May 1992 on the **conservation of natural habitats and of wild fauna and flora**	38	33	129	205	11	77	13	6	64	52	35	15	18	26	66	13	39
Directive 94/22/EC	Directive 94/22/EC of the European Parliament and of the Council of 30 May 1994 on the conditions for **granting and using authorizations for the prospection, exploration and production of hydrocarbons**	8	0	3	7	2	1	1	0	7	6	5	8	2	3	3	5	8
Directive 98/83/EC	Council Directive 98/83/EC of 3 November 1998 on the **quality of water intended for human consumption**	4	0	8	5	3	3	9	1	30	8	1	11	2	8	3	0	45
Directive 2000/60/EC	Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a **framework for Community action in the field of water policy**	10	5	36	5	17	36	6	36	47	41	13	54	4	11	23	9	108
Directive 2001/42/EC	Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the **assessment of the effects of certain plans and programmes on the environment**	1	0	28	47	3	5	7	34	2	27	3	5	1	1	1	2	6
Directive 2003/87/EC	Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a **scheme for greenhouse gas emission allowance trading** within the Community and amending Council Directive 96/61/EC	49	20	111	13	3	13	5	1	17	24	7	5	2	11	6	5	6
Directive 2004/35/EC	Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on **environmental liability with regard to the prevention and remedying of environmental damage**	2	0	27	13	3	10	2	1	12	32	2	5	2	4	1	5	6
Directive 2006/118/EC	Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the **protection of groundwater against pollution and deterioration**	2	0	2	2	3	14	11	1	8	17	11	13	1	3	2	10	10
Directive 2006/21/EC	Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the **management of waste from extractive industries** and amending Directive 2004/35/EC - Statement by the European Parliament, the Council and the Commission	6	5	6	21	4	20	12	2	16	44	5	8	3	2	4	22	21
Regulation (EC) No 1907/2006	Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the **Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)**, establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC	63	3	36	Directly Applicable													
Directive 2008/98/EC	Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on **waste** and repealing certain Directives	9	2	8	6	2	32	4	2	30	33	6	31	1	13	1	20	9
Regulation (EC) 1272/2008	Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on **classification, labelling and packaging of substances and mixtures**, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006	0	0	0	Directly Applicable													
Directive 2009/147/EC	Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the **conservation of wild birds**	1	0	5	32	0	18	0	1	0	1	0	3	0	18	2	0	13
Directive 2010/75/EU	Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on **industrial emissions (integrated pollution prevention and control)**	29	28	8	18	7	28	10	3	41	51	3	11	2	1	2	27	5

EU LEGISLATION					NATIONAL IMPLEMENTING LEGISLATION													
Instrument Name	**Title**	**Follow-on EU Instruments**	**DECISIONS**	**CASELAW Judgements**	**AUT**	**BGR**	**DNK**	**FRA**	**DEU**	**HUN**	**LTU**	**NLD**	**POL**	**PRT**	**ROU**	**ESP**	**SWE**	**GBR**
Regulation (EU) No 994/2010	Regulation (EU) No 994/2010 of the European Parliament and of the Council of 20 October 2010 **concerning measures to safeguard security of gas supply** and repealing Council Directive 2004/67/EC	1	0	0	Directly Applicable													
Directive 2011/92/EU	Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the **assessment of the effects of certain public and private projects on the environment**	4	0	9	1	1	10	0	1	38	1	0	0	3	0	1	0	0
Regulation (EU) No 528/2012	Regulation (EU) No 528/2012 of the European Parliament and of the Council of 22 May 2012 concerning the **making available on the market and use of biocidal products**	28	15	11	Directly Applicable													
Directive 2012/18/EU	Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the **control of major-accident hazards involving dangerous substances**, amending and subsequently repealing Council Directive 96/82/EC	3	2	0	37	3	15	6	1	9	39	2	8	2	2	4	11	15
Directive 2013/59/Euratom	Council Directive 2013/59/Euratom of 5 December 2013 laying down **basic safety standards for protection against the dangers arising from exposure to ionising radiation**, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom	2	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0
Regulation (EU) No 525/2013	Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 May 2013 on a **mechanism for monitoring and reporting greenhouse gas emissions** and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC	4	0	0	Directly Applicable													
Recommendation 2014/70/EU	**Recommendation of 22 January 2014 on minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high-volume hydraulic fracturing**	0	0	0	Directly Applicable													
Directive 2014/52/EU	Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU on the **assessment of the effects of certain public and private projects on the environmen**t	1	0	0	0	0	0	4	0	0	2	0	0	0	0	0	0	0
Directive (EU) 2015/1127	Commission Directive (EU) 2015/1127 of 10 July 2015 amending Annex II to Directive 2008/98/EC of the European Parliament and of the Council on **waste** and repealing certain Directives	2	0	0	0	0	1	0	1	3	1	1	0	1	1	1	1	5

Table E - (from AEA 2012-08 - Table ES2: Summary of gaps and potential gaps in European legislation)

EU Legislation	Discretion / Uncertainty	Impact	Risk associated with gap/potential gap
Gaps in legislation			
Environmental Impact Assessment Directive (2011/92/EU) [and 2014/52/EU that comes into force in2017-05]	Annex I threshold for gas production is above HVHF project production levels. Result: no compulsory EIA.	All, especially relevant to key impacts from land-take during preparation, noise during drilling, release to air during fracturing, traffic during fracturing and groundwater contamination	A decision on the exploration and production may not be based on an impact assessment. Public participation may not be guaranteed, permits may not be tailor-made to the situation Impacts may not be known and assessed. Measures to mitigate possible impacts may not be applied through consent process or permitting regime.
Environmental Impact Assessment Directive (2011/92/EU)	Annex II no definition of deep drilling; exploration phase would not be covered under Annex II classification "Surface industrial installations for the extraction of coal, petroleum, natural gas and ores, as well as bituminous shale". Result: no compulsory EIA	All, especially relevant to key impacts from land-take during preparation, noise during drilling, release to air during fracturing, traffic during fracturing and groundwater contamination	A decision on the exploration and production may not be based on an impact assessment. Public participation may not be guaranteed, permits may not be tailor-made to the situation. HVHF project involving shallow drillings not covered by EIA. For these projects, impacts may not be known and assessed. Measures to mitigate possible impacts may not be applied through consent process or permitting regime. Preventative measures may not be undertaken. Aquifers in surroundings not known, leading to unanticipated pollution.
Environmental Impact Assessment Directive (2011/92/EU)	No explicit coverage of geomorphological and hydrogeological aspects, no obligation to assess geological features as part of the impact assessment	Especially relevant for groundwater contamination, seismicity, land impacts, release to air	No assessment of geological and hydrogeological conditions (e.g. natural and manmade faults, fissures, hydraulic connectivity, distance to aquifers, etc) in the frame of the impact assessment or screening, resulting in sub-optimal site selection and risks of subsequent pollution Monitoring of groundwater quality of aquifers in surrounding of the site may not be done and preventative measures not undertaken. Aquifers in surroundings not known, leading to unanticipated pollution.
Water Framework Directive (2000/60/EC)	WFD programmes of measures are not required to be enforced until 22.12.2012	Abstraction of water and impacts due to water contamination	Inadequate monitoring and measures to prevent these impacts
Water Framework Directive (2000/60/EC)	For substances which are not pollutants, the WFD does not prevent direct fracturing into groundwater that may ultimately impact aquifers	Pollution of groundwater	"Pollutants" are defined as "any substance liable to cause pollution, in particular those listed in Annex VIII." Permit conditions may not require monitoring or measures to prevent hydraulic fracturing leading to impacts on aquifers
Mining Waste Directive (2006/21/EC)	No reference document on Best Available Techniques (BREFs)	Waste management as covered by MWD – treatment of hydraulic fracturing fluids during and after fracturing	No shared opinion on Best Available Techniques nor enforcement of those techniques Higher levels of pollution arising from the management of mining waste
Directives on Emissions from Non-Road Mobile Machinery (Directive 97/68/EC as amended)	Lack of emission limits for off-road combustion plant above 560 kW	Air pollution especially during drilling and fracturing	Measures may not be taken to prevent high emissions to air, leading to localised increased air pollution, although purpose of legislation is to regulate machine standards not emissions during use.
IPPC Directive (2008/1/EC) and IED (2010/75/EC)	No BREF for drilling equipment	Air pollution especially during drilling and fracturing	Measures may not be taken to prevent high emissions to air, leading to localised increased air pollution. This potential gap arises because of uncertainty over the hazardous character of fracturing fluids which would determine the applicability of the IPPC Directive (2008/1/EC) to hydraulic fracturing installations
The Outdoor Machinery Noise Directive2000/14/EC	Gaps in limits to prevent noise for specific equipment	Noise during drilling	Drilling equipment used in HVHF processes however is not included in the equipment cited in this directive. Compressors used for drilling have a power capacity over 350 kW, which is the limit for this directive
Air Quality Directive (2008/50/EC)	Not specific about remedial measures or prohibition of polluting activities	Air pollution during drilling and fracturing and traffic impacts	No measures to reduce emissions to air. Levels of air pollution may be above impact levels or air quality standards.
Environmental Liability Directive (2004/35/EC)	Damage caused by non Annex III activities not covered unless it is damage to protected species and natural habitats resulting from a fault or negligence on part of operator. Impacts caused by diffuse pollution are not covered, unless a causal link can be established	Land-take, air impacts during drilling and fracturing and traffic	Some environmental impacts may not be covered.
Uncertainties in application			
IPPC Directive (2008/1/EC) and IED (2010/75/EC)	Activity not mentioned or may not be covered under hazardous waste or combustion capacity	Emissions to air, water and soil	No permit obligation under IPPC and no BREF under IPPC or IED .This potential gap arises because of uncertainty over the hazardous character of fracturing fluids which would determine the applicability of the IPPC Directive (2008/1/EC) to hydraulic fracturing installations The monitoring requirements as mentioned in IPPC directive may not be applied. Integrated measures designed to prevent or to reduce emissions in the air, water and land, including measures concerning waste, in order to achieve a high level of protection of the environment may not be taken. Monitoring of emissions to air might not take place
Mining Waste Directive (2006/21/EC)	Uncertainty over classification of Category A waste facility	Major accidents, groundwater and surface water pollution, air impacts	The classification may be inadequately performed Major accidents might occur without proper prevention and emergency plans.

Seveso II Directive (96/82/EC)	Uncertainty over whether the Directive covers high volume hydraulic fracturing (HVHF), subject to storage of natural gas or of specific chemical additives on-site.	Major accidents involving dangerous substances (e.g. water pollution events)	Major accidents might occur without proper prevention and emergency plans.
Issues currently at the discretion of Member States			
The Strategic Environmental Assessment Directive (2001/42/EC)	Remains up to Member States to decide whether or not a plan or programme might have significant effects	All	No SEA would be made Information on possible environmental effects would not be available and therefore would not be used in an authorisation/consent process or permits
Environmental Impact Assessment Directive (2011/92/EU)	Member States must decide whether an EIA is required (Article 4(2)) for activities covered by Annex II.	All	No EIA would be made. The environmental impacts would not be assessed and properly described. The measures that can prevent or mitigate the impacts will not be presented
Hydrocarbons Authorization Directive (94/22/EC)	No compulsory account of environmental aspects	All	Member States may not take account of environmental impacts during the authorisation process
Mining Waste Directive (2006/21/EC)	Member States decide on the permit and the control measures	Waste management as covered by MWD – treatment of hydraulic fracturing fluids during and after fracturing	There may be inadequate measures for the monitoring and control of impacts related to management of mining waste
IPPC Directive (2008/1/EC)	Member State decisions on monitoring and inspection	Emissions to air, especially during drilling and fracturing, and releases to water during fracturing	There may be inadequate measures for the monitoring and control of impacts related to air and water emissions
Air Quality Directive(2008/50/EC)	Member States responsible for making plans to meet the AQ standards	Emissions to air, especially during drilling, fracturing and traffic, and releases to water during fracturing	No specific measures for emission abatement may be required. Air pollution may not be prevented or mitigated.
Water Framework Directive (2000/60/EC)	Member State determination of control measures related to abstraction	Water use during fracturing	There may be unmitigated or poorly controlled impacts arising from water use during abstraction
Noise Directive (2002/49/EC)	Up to Member States to set noise levels and to make plans to meet these levels	Noise during drilling and fracturing and traffic during fracturing	No specific measures for noise abatement may be required. Noise may not be prevented or mitigated

5 Legislation and regulation governing shale gas at a member state level

5.1 EU research

EU research has been undertaken on national level laws relating to permitting and regulation of the shale gas industry as follows:

Surveys of national level legislation and regulation	AUT	BGR	DNK	FRA	DEU	HUN	LTU	NLD	POL	PRT	ROU	ESP	SWE	GBR
Philippe & Partners 2011-08				x	x				x				x	x
Milieu 2013-08		x	x		x		x		x		x	x		x
Milieu 2016-02	x		x		x	x	x	x	x	x	x	x		x

The results of this research is set out in Tables F (Philippe & Partners 2011) and G (Milieu 2016 - the pertinent findings of the Milieu study of 2013 were updated during the 2016 study).

5.2 Member States moratoriums and bans on shale gas exploration and fracking

The French parliament voted to ban fracking in 2011 effectively invoking the precautionary principle, in the process overturning a number of licensed concessions. The legality of this new law was challenged by Schuepbach Energy, and on 11th October 2013 the French constitutional court ruled that the law banning hydrofracking and cancelling the concessions was both constitutional and absolute. This law will be in force for the foreseeable future.

The Scottish parliament imposed a moratoria on shale gas exploration in January 2015, and on 1st June 2016 voted to implement an outright ban on all shale gas hydrofracking. On 3rd November 2016 a proposed bill "*A proposal for a Bill to ban unconventional oil and gas extraction, including by means of hydraulic fracturing*" was tabled for consultation; and it is not certain at this moment whether this non-binding but persuasive parliamentary vote banning fracking will transition to an absolute legally enforceable law. For the time being the moratorium remains in place.

On 24th June 2016 the German parliament passed a law that banned hydraulic fracturing for the production of shale gas and shale oil and any further exploration for unconventional hydrocarbons. The new regulations amended both the national water law and mining law and will be in force for the foreseeable future.

For the purposed of this report, further research regarding France, Germany and Scotland is suspended (although previous research findings on these countries is included in Tables F and G).

5.3 Milieu and Ricardo review of February 2016

For the purpose of this legislative review, the findings of the 2016 Milieu and Ricardo study are directly relevant and constitute as complete an analysis of the implementation of EU law in the

selected member states as is likely to be established in the near future. It is however already out of date, in so far as Germany has now joined France in an absolute ban on shale gas hydrofracking, and new legislation will continue to come into force, so its finding will need to be reviewed periodically.

The methodology used in the report was robust and thorough, selecting a number of case studies by member state, and then asking national experts to analyse whether the regulatory processes in the nationally relevant case studies applied the principles of the Recommendation and selected legal requirements under the following EU legal texts:

- Directive 94/22/EC (Hydrocarbons Directive)
- Directive 2001/42/EC (SEA Directive)
- Directive 2011/92/EU (EIA Directive)
- Directive 2010/75/EU (IED)
- Directive 96/82/EC (Seveso II)
- Directive 92/43/EEC (Habitats Directive)
- Directive 2009/147/EC (Wild Birds Directive)
- Regulation (EU) No 525/2013 GHG Monitoring Regulation) and Decision No 406/2009/EC (ESD)
- Directive 2008/98/EC (Waste Framework Directive)
- Directive 2006/21/EC (Extractive waste Directive)
- Directive 2000/60/EC (Water Framework Directive)
- Directive 2006/118/EC (Groundwater Directive)
- Directive 2013/59/Euratom (exposure to ionising radiation)

The findings from the Milieu and Ricardo study are reproduced as Table G and in Annex 1 at the end of this report. The study confirmed the conclusions arrived at by the EU Commission and its earlier EU funded reports (see the studies listed in Tables A & B above - where every report reached the same conclusion) that the latitude and discretion allowed by the current EU legislation (which is mainly in the form of Directives - which have to be transposed into each member states regulatory framework of laws and regulation) has meant that member states law and regulations significantly differ from one another (see Tables E, F and G and Annex 1 for details of gaps, discretions, and their consequent differences).

Table F - Findings extracted from the EU Commission Final Report on Unconventional Gas in Europe in the framework of the multiple framework service contract for legal assistance (Philippe & Partners 2011)

Regulatory Issue	Poland	France	Germany	Sweden
Permitting				
Information to submit to the authority approving the activity	The applicant needs to meet the information requirements laid down under Directive 85/337/EEC.	The information varies depending on whether the E.I.A. is carried out under Article R 122-3 of the Environmental Code109 or under Article R 122-20 of the same Code.	The applicant's documents contain information on the possible impact of the project on the environment primarily.	It varies depending on the type of activity and the place: Exploration and prospection are type C activities111 Production is, in principle, a type B activity112 Production in mountainous areas is a type A activity.
The criteria for determining whether or not to perform an EIA (Pt I)	Exploitation activities: "Annex II projects" (as defined under Directive 85/337/EEC) may require an E.I.A., i.e. projects in the field of the extractive industry (or "projects likely to have significant impact on the environment"). The decision is based on a "screening procedure", on a case-by-case basis, on the basis of the criteria defined in Annex III of the Directive. The screening procedure results in an "environmental decision" which needs to be issued regardless of the outcome of the screening procedure.	"Annex II projects" (as defined under Directive 85/337/EEC) require an E.I.A.. Any "Autorisation d'Ouverture de Travaux Miniers" (or AOTM), i.e. the document submitted along the application for an exploration licence, requires an E.I.A. As a rule, projects having a total	An integral part of the framework operation plan (in form of planning approval) for any project in which the aimed extraction exceeds 500k m^3/day. The Land of North Rhine Westphalia has filed a motion in the Bundesrat to make the E.I.A.-obligation part of all	Type C activities require an E.I.A. "if deemed necessary". Type B activities require an E.I.A. for the permit application process. Type A activities always require an E.I.A.
The criteria for determining whether or not to perform an EIA (Pt II)	Production activities: Such activities will be, as a rule, considered as "annex I" projects, for which an E.I.A. must be performed. Projects of minor nature would be considered as "annex II projects", for which a screening procedure is mandatory. The E.I.A. requirement is to be fulfilled under the procedure leading to an "environment decision" and is required for activities falling within the scope of the Act on Access to Environmental Information and its Protection.	N/A	N/A	N/A
The interested parties the information must be made available to	The public affected or likely to be affected by or having an interest in the environmental decision-making procedure.	Any OATM requires a local consultation before delegates of the concerned territorial collectivities and associations of environmental protection.	Competent authorities (Land ministry of economic affairs or environment, mining authorities) must make the information available to the public. Anyone is allowed to consult the documents without having to demonstrate any particular individual/subjective interest/affliction.	During the authorisation procedure the CAB must be consulted by the Mining Inspectorate at an early stage with a view of obtaining its input on nature reserve, cultural heritage, rail road issues etc as well as regarding the E.I.A. during the procedure to obtain an exploitation authorisation. Individuals who are likely to be affected must be consulted in good time and to an appropriate extent before the application submission In case of E.I.A., the candidate must consult the other government agencies, the municipalities, the citizens and the organisations that are likely to be affected.
Prior public consultations	"One or more natural or legal persons and, in accordance with national legislation or practice, their associations, organisations or groups". The scope of the public to be consulted may not be limited in any way.	Any project "of regulatory state decision" (…) "having a significant and direct impact on the environment" must be subject to public participation for at least fifteen days before any "compulsory consultation of committees having persons directly affected as their members".	The public must be consulted prior to any decision; it must have the opportunity to submit statements.	See previous answer.
Information available to the public (including how it is made available)	Anyone may submit a request for access to the environmental information. The competent authority decides whether or not to grant the information. In case of refusal, it must issue a decision. At the time of submitting the present interim report, we do not know on which ground such a refusal may be done.	The decision granting the title/AOTM; The E.I.A.	The information made available to the public is: Description of the contemplated activity; Description of the measures aiming at minimising possible environmental impact and restoration measures; Non-technical summary; Any other document that the competent authority deems relevant. The documents must be displayed to the affected community for one month.	The E.I.A. and the application for the environmental hazardous activity are published in the local newspaper. Anyone may request additional information after a secrecy check is performed by the relevant authority (on the basis of the Public Access to Information and Secrecy Act).
Environmental Liability				
Triggering event	No fault needed. Environmental liability provisions apply to "imminent threat of damage to the environment or damage to the environment caused by an activity posing a risk of damage to the environment and/or caused by	No fault needed for a list of activities subject to a strict liability regime. Different aspects related to shale gas activities fall under this strict liability regime (e.g. use of chemical substances, waste management, water	Under the environmental liability act, fault is needed. This is based on the fact that there is a list of activities subject to a strict liability regime, to which shale gas activities do not belong. Consequently, shale gas activities require a	No proof of fault is required. There is no need to have a wilful misconduct. "Persons who pursue a harmful activity or cause it to be pursued in their capacity as property owners or land leaseholders shall be liable for

Regulatory Issue	Poland	France	Germany	Sweden
	other activities if they relate to protected species or protected natural habitat".	injection).	fault for provisions on environmental liability to apply.	compensation for damage. Any other person who pursues the harmful activity or causes it to be pursued and uses the property in his business activities or in public activities shall also be liable for compensation."120
Preventive measures	Yes. In case of imminent threat of damage to the environment, obligation to take preventing actions immediately.	Yes. In case of imminent danger, obligation to take all necessary measures immediately.	Yes. In case of imminent threat, obligation to take all necessary measures immediately and to inform the competent authority.	Yes. The mere risk of damage or detriment involves an obligation to take the necessary measures to combat or prevent adverse health and environmental effects.
Restorative measures	Yes. Obligation to take action to limit damage to the environment and to prevent any further damage.	Yes. Obligation to put things back into their pristine state (ecological system, wildlife and landscape). A strict procedure regarding the adoption of these measures and the monitoring of their implementation is foreseen.	Yes. Obligation to take actions to limit damage and the necessary remedial measures.	Yes. Obligation to take remedial measures to eliminate damage upon request of a supervisory authority. Restorative measures may include a duty to prevent further damage and/or to restore things into their pristine state.
Costs of remedy and/or preventive measures	Born by the responsible entity.	Born by the responsible entity.	Born by the responsible entity. The State may take a deviant scheme but this right was not implemented so far.	Born by the responsible entity. The extent of the liability shall be determined according to a cost/benefit assessment. If there are several operators they will be jointly accountable for the remediation that has been deemed necessary. If the operator is not able to carry out or pay for the remediation of polluted property, the property owner may under certain circumstances be liable in the second instance.
Possibility to undertake legal actions	Anyone has the right to report to the competent authority any threat of damage or damage. It remains unclear who is entitled to take legal action (individuals and/or the competent authority).	The affected persons/entities are entitled to report to the competent authority any threat of damage or damage. The competent authority takes legal actions.	Any affected person or NGO active in environment protection may request the competent authority to take action in case of threat of damage or damage.	Persons who suffer damage can bring legal claims before Land and Environmental Courts.
Water				
Clean water use	Assessment under E.I.A. Permit Taken into account by State Mining Authority in approving detailed plan of operations for mining plant	Declaration or authorisation	Permit or approval	Notification under EC Approval under E.I.A. or separate permitting procedure (exploration) permit (exploitation)
Waste water disposal	Assessment under E.I.A. Permit Taken into account by State Mining Authority in approving detailed plan of operations for mining plant	Declaration or authorisation	Direct discharge of waste water requires a permit	Notification under EC Approval under E.I.A. or separate permitting procedure (exploration) Permit for environmentally hazardous activities (exploitation)
Injection of water for hydrocarbons exploration and extraction	Permit Taken into account by State Mining Authority in approving detailed plan of operations for mining plant	Declaration or authorisation	Drilling or digging works that may affect ground water are subject to a prior notification or a permit	Notification under EC Approval under E.I.A. or separate permitting procedure (exploration) Permit for environmentally hazardous activities (exploitation)

Table G - Findings extracted from the EU Commission review of the implementation of Recommendation 2014/70/EU (Milieu & Ricardo 2016-02) - See ANNEX 1 at the end of this report for a full reprint of the salient findings

Article in EU Recommendation 70/2014/EU	Austria	Germany	Denmark	Spain	Hungary	Lithuania	Netherlands	Poland	Portugal	Romania	UK
3.2 - Rules on possible restrictions of activities											
Rules on restrictions targeting hydraulic fracturing			x			x	x				x
Rules on restrictions applying to several activities including hydrocarbon exploration and production			x			x		x		x	
3.3 & 3.4 - EIA in accordance Directive 2011/92/EC											
No EIA nor screening carried out at some of the examined sites					x			x			
Screening carried out at all sites examined	P	x				x				x	
Screening carried out at some of the examined sites				x				x			x
EIA carried out at some of the examined sites								x			x
EIA carried out at all examined sites			x	x						x	
3.3 & 3.4 - Opportunities for Public participation in EIA procedures											
Preliminary public consultation timeframe			28 days	30 days				30 days		45 days	4 months
EIA public consultation timeframe			8 weeks	>30 days				30 days		22 days	12 weeks
EIA overall timeframe in practice			22 months	>24 months				6 - 8 months		<3 months	18 months
3.3 & 3.4 - Scope of the EIA											
Specific EIA requirements for hydraulic fracturing	x	x	x	x		x			x		
Specific thresholds for EIA or screening (e.g. depth of drilling; presence of sensitive areas or size of the installation)					x		x	x			x
EIA Directive requirements										x	
3.3 & 3.4 - EIA thresholds applying to the exploration and production of hydrocarbons (such as shale gas) using HVHF											
The exploration and exploitation of rock layers in unconventional oil and gas deposits through hydro-mechanic fracturing ('frac treatment') is subject to an EIA.	x										
No specific requirements or thresholds related to HVHF. If the production rate is larger than 500 tons of oil/day resp. 500,000 m³ of gas/day, a formal procedure with EIA is mandatory. An EIA is also mandatory for the establishment and operation of drilling platforms in the areas of coastal water and in the continental shelf. The current German law does not refer to deep drilling as a criterion to trigger an EIA screening procedure. In the draft Regulation of the Federal Ministry of the Economy and Energy for the introduction of EIAs in the use of fracking technology and deep drilling (not yet adopted), an EIA would become compulsory for projects that plan to carry out hydraulic fracturing in both conventional and unconventional hydrocarbon deposits.		x									
Projects where fracturing is planned for the exploration or extraction of shale gas are subject to a compulsory EIA.			x								
All projects involving drilling for the prospection, exploration, or exploitation of hydrocarbons, CO2 storage, gas storage and medium and high geothermal enthalpy, which require the				x							
No specific requirements or thresholds related specifically to HVHF. The requirements of the EIA Directive related to oil and gas production apply. A screening procedure must be applied in the following cases: a) Below the production threshold of gas production of 500'000 m3/day), oil 500 tons/day without size limitation. b) Exploratory drilling in protected natural zones, Natura 2000 zones, protected areas of caves, protected areas of underground water (if the start of the operation is not excluded by legislation on the protection of water resources and drinking water facilities).					x						
An EIA is required for the activity of extraction or (and) direct exploration of unconventional hydrocarbons using hydraulic fracturing.						x					

Article in EU Recommendation 70/2014/EU	Austria	Germany	Denmark	Spain	Hungary	Lithuania	Netherlands	Poland	Portugal	Romania	UK
No specific requirements or thresholds related to HVHF. The requirements of the EIA Directive related to oil and gas production apply. In case of deep							x				
A screening procedure is required for the following prospecting or exploration of mineral deposits: · located in offshore waters of Poland, · underground mining, · carried out using borehole techniques, at depths below 1 000 m o a)in water intake protection zones, o b)in inland water reservoirs protection zones o c)in areas covered by nature protection schemes or in buffer zones for nature protection schemes , · carried out using borehole techniques at depths below 5000 m in other areas (not listed in c)								x			
EIAs are mandatory since September 2015 for “exploratory drillings (sondagem) and/or extraction of hydrocarbons by unconventional methods (including hydraulic fracturing)”.									x		
Literal transposition of the EIA Directive thresholds										x	
The requirements of the EIA Directive related to oil and gas production apply. An EIA screening is required for deep drilling projects, where the area of the works exceeds 1 hectare, and surface industrial installations for the extraction of petroleum, where the development exceeds 0.5 hectares. It should also be noted that following the changes introduced by the Infrastructure Act 2015, new section 4A(3) of the Petroleum Act 1998 (not yet in force; will apply only to England and Wales) requires that the Secretary of State must be satisfied that the environmental impact of the development has been taken into account by the local planning authority, before issuing a hydraulic fracturing consent (this is required for any activity where hydraulic fracturing is carried out at a depth of 1000 metres or more in connection with the use of the relevant well to search or bore for or get petroleum21). While this does not alter the requirements for an EIA or screening, the local planning authority will be required in all cases to confirm, by providing a notice that the environmental information was taken into account in deciding to grant the relevant planning permission.											x

6 FracRisk science: policy, legislation, and regulation

6.1 Place of FracRisk science within environmental law and regulation

Project FracRisk seeks to understand the physics of hydraulic fracturing and associated processes within a shale gas play (fracking fluid/gas migration, induced seismicity); to quantitatively assess the uncertainty of numerically modelling these activities and their consequences; to establish regional generic databases of the physical properties relevant to shale gas exploration and exploitation within Europe; and to build a robust risk mitigation methodology (including optimised monitoring programmes) based on a quantitative feature-events-processes (FEP) approach and bow-tie risk assessment model, with the aim of making this methodology publically available as a freeware software programme, so that operators, regulators and other interested parties can rapidly, cheaply, and (very importantly) robustly assess the geohazards presented by any given horizontally drilled and hydrofracked shale gas well proposal.

Project FracRisk's research is in-depth and narrowly focused on one specific aspect of shale gas operations (i.e. fracking geohazard), and has maximum impact, in so far as legislation and regulation is concerned, at the permitting stage of a project life-cycle, as part of the risk assessment processes; where necessary methods of environmental exposure and mitigation will be agreed before a project is permitted to proceed. FracRisk risk assessments will also feed into the operational risk management of a project through the optimised design of any subsurface geohazard monitoring programme and the "traffic-light" thresholds of any site assurance regime.

However, as is apparent from the analyses of existing EU legislation and member state regulation that has been collated and presented in this Interim Legislative Review (refer to Tables E, F and G above, and Annex 1 below); the EU level law gives significant discretion to each member state as to when and how to implement the risk assessment and risk mitigation processes within their national permitting process. The provisions of the current version of EU EIA legislation (Directive 2011/92/EU and its soon to be "in force" amending Directive 2014/52/EU) have no requirement that a risk assessment need be anything other than qualitative. Moreover, as far as it has been ascertained to date, there is no subordinate legislation within any of the EU member states requiring that a quantitative assessment of geohazard be undertaken as part of the permitting process.

From a scientific perspective, in the absence of fully deterministic information on any given system (which is necessarily the case when examining the subsurface), stochastic approaches to modelling and quantifying uncertainty are the most robust and thorough means of defining the probability associated with a given configuration of a system, such as the physical condition of the rocks in the region of a proposed well play.

Such properly conducted analysis and modelling effectively creates "best practice" expert evidence, which would be available to regulators (and their political masters) to assist in decision making. In the political context, especially where the precautionary principle has been invoked (either expressly (e.g. France) or implicitly (Germany, Scotland); the use of the principle of "precaution" is required to

periodically examine the current state of the art understanding of the science and technology pertaining to any ban made on the basis of precaution. EU funded science research of UH exploration and exploitation addresses such deficiencies in shale gas knowledge and understanding.

To put the FracRisk science into some sort of EU policy context, it is worth understanding other research that the EU has commissioned into shale gas horizontal well hydrofracking, and seeing where the FracRisk science fits into this wider research programme.

6.2 EU risk assessment of hydraulic fracturing in horizontal well and for other UH

Two EU funded reports undertook detailed examination of the operational risks associated with the activities typically employed by the onshore upstream unconventional oil and gas industry (AMEC and Phillippe & Partners 2014-08 "*Technical Support for Assessing the Need for a Risk Management Framework for Unconventional Gas Extraction - Final Report*" and AMEC 2015-08"*Technical Support for Assessing the Need for a Risk Management Framework for Unconventional Gas Extraction - Final Report*"). These reports used many of the findings regarding risk from the EU funded report by AEA 2012-08 "Support to *the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe - Final Report*".

The risks (including risks from horizontally drilled and hydrofractured recovery of shale gas) were analysed from an environmental and regulatory perspective. The risk assessments examined the project lifecycle, and for shale gas operations, identified over 200 non-business-as-usual (non BAU) measures needed to mitigate them, where a BAU measure is an action already required by the acquis). The measures were categorised into "themes" and were grouped as follows: zoning; underground risks; chemicals; water depletion; surface water quality; air quality; waste; post closure; public acceptance; and other measures.

The report priced the likely annual cost of implementing non-BAU mitigation measures based on tiers of "levels of ambition" (different levels of effectiveness of prevention of risk) around a hypothetical and generic "illustrative Concession" model. The European Commission requested that the costs for implementation of the non-BAU's be categorised into the four following policy options:

- 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.

Project FracRisk science extends this work undertaken in 2014 and 2015 by strengthening the robustness of the geohazard risk assessment to assist in costing the implications of each policy option; as well as providing a robust methodology that can be incorporated within such a policy for use in the permitting process.

7 Summary and further work

7.1 Summary

This Interim Legislative Review is the first of three reports concerned with the regulatory regime in the EU and across select member states; and has surveyed the current EU level legislation and taken cognisance of the latest EU research into the science of horizontally drilled wells and hydrofracking for shale gas exploration and exploitation; and has collated surveys of member state regulations governing behaviours and practices within a selection of member states. It is intended that this document will be amended periodically as the regulatory regime evolves.

It has independently established during this review that cutting edge science, such as that being undertaken by FracRisk, is currently not legally integrated into the regulatory process, and that it has a place within regulation as part of both the permitting process (risk assessment) and operational process (risk management).

There are currently no specific requirements in any regulatory regime in the EU that require full quantitative modelling of fluid and gas flow or induced seismic activity within the geosphere, nor that the results of such modelling be used within a quantitative risk assessment framework such as is being researched and developed by the FracRisk team.

Although there is indeed recognition at a EU level that the use of such research is helpful is reducing uncertainty in decision making during the permitting process; at the moment the legislation gives the member states wide discretion as to the scope and level of rigour and detail of any risk assessment required at law to establish the safety of an operation.

7.2 Follow-on work

In the process of reviewing and collating previous EU funded research, and the process of undertaking a wider literature review for this Interim Review, a number of specialist themes have become apparent that will be the subject of additional Annexes to this report and which will feed into the later planned reports.

These themes are:

- use of stochastic approaches as a best-practice standard of legal evidence for its incorporation into the legal process of permitting (EIA);
- the "precautionary principle" and the role of scientific evaluation of risk to achieve and exceed legal tests of evidence, such as at a standard of "on the balance of probabilities".

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ANNEX 1 - Milieu and Ricardo 2016

Articles 1 to 16 of Recommendation 2014/70/EU and the their general implementation by member states (taken from Sections 3 and 4 of the report by Milieu & Ricardo 2016-02)
Recommendation 2014/70/EU
1. PURPOSE AND SUBJECT MATTER *1.1. This Recommendation lays down the minimum principles needed to support Member States who wish to carry out exploration and production of hydrocarbons using high-volume hydraulic fracturing, while ensuring that the public health, climate and environment are safeguarded, resources are used efficiently, and the public is informed.* *1.2. In applying or adapting their existing provisions implementing relevant Union legislation to the needs and specificities of exploration and production of hydrocarbons using high-volume hydraulic fracturing, Member States are encouraged to apply these principles, which concern planning, installation assessment, permits, operational and environmental performance and closure, and public participation and dissemination of information.*
2. DEFINITIONS *For the purpose of this Recommendation:* *(a) 'high-volume hydraulic fracturing' means injecting 1 000 m3 or more of water per fracturing stage or 10 000 m3 or more of water during the entire fracturing process into a well;* *(b) an 'installation' includes any related underground structures designated for the exploration or production of hydrocarbons using high-volume hydraulic fracturing.*
3. STRATEGIC PLANNING AND ENVIRONMENTAL IMPACT ASSESSMENT *3.1. Before granting licenses for exploration and/or production of hydrocarbons which may lead to the use of high-volume hydraulic fracturing, Member States should prepare a strategic environmental assessment to prevent, manage and reduce the impacts on, and risks for, human health and the environment. This assessment should be carried out on the basis of the requirements of Directive 2001/42/EC.*
Only Lithuania, the Netherlands and the UK prepared a SEA prior to the grant of licenses which may have led to the use of HVHF. *In the Netherlands, as part of the National Spatial Strategy on Shale Gas, the government decided to prepare a SEA specifically targeting shale gas extraction which was finalised in July 2015.The list of environmental aspects covered by this SEA is comprehensive and encompasses all expected impacts and risks of unconventional gas extraction and all phases of exploration, including closure. The SEA covers all the national territory.* *The public concerned was provided with an early and effective opportunity to participate in the development of the scope of the SEA, as evidenced by the relatively high number of responses received. Public participation on the prepared SEA itself is foreseen in early 2016 as part of the preparation of the National Strategy on Underground, following the development of an Energy Report in late 2015. The SEA contributed to the political discussion on shale gas development.* *In the UK, the SEA assessed the environmental effect of the draft Licensing Plan related to the 14th and potential further rounds of onshore oil and gas licensing in landward areas in parts of England, Scotland and Wales. HVHF gas extraction plans were therefore subject to SEA within the wider context of the oil and gas licensing rounds and considered alongside conventional oil and gas extraction in those areas. The SEA however considered the specific environmental effects of hydraulic fracturing during the exploration and production stages of unconventional oil and gas exploration. It assessed the potential activities that could follow on from the licensing round and which may have environmental effects, and more specifically the effects associated with the six exploration and production stages (non-intrusive exploration, exploration drilling, production development, production/ operation/ maintenance, decommissioning of wells, and site restoration and relinquishment) for each activity of conventional oil and gas, shale gas, virgin coalbed methane and gas storage. The public concerned had early and effective opportunities to participate in developing the Licensing Plan and the Updated Environmental Report took into account their responses. The revised Environment Report was issued for public consultation between 17 December 2013 and 28 March 2014.* *In Lithuania, SEAs were carried out prior to the public tender procedure to grant licenses for the prospecting, exploration and exploitation of (unconventional) hydrocarbons for the Šilutės–Tauragės 1800 square km area in 2011 and for the Rietavas 1599 square km area in 2006 . The SEA Reports do not specifically indicate and/or cover HVHF and were prepared according to the broader plans or programmes related to oil and gas extraction development strategies in Lithuania. However they cover all aspects of oil and gas prospecting, exploration and extraction and indirectly several aspects linked to the use of HVHF. The public was informed on how to access the SEA Report and on how to provide comments and on the dates of the public meeting and any other relevant information. The public and competent authorities had the opportunity to give their opinions. Comments were taken into account in the course of the planning procedure. The Šilutės– Tauragės SEA Report was under public consultation between 6 June 2011 and 8 July 2011.* *In Portugal no SEAs have been carried out so far for oil and gas exploration and/or production in general. There is no plan or programme on exploration and production of hydrocarbons by unconventional methods ongoing at this stage, and according to the National Entity for the Fuels Market (ENMC), unconventional methods have not been used so far for the exploration of hydrocarbons. ENMC mentioned that in case the use of unconventional methods proves to be a "strong possibility", a SEA would be required.*
3.2. Member States should provide clear rules on possible restrictions of activities, for example in protected, flood-prone or seismic-prone areas, and on minimum distances between authorised operations and residential and water-protection areas. They should also establish minimum depth limitations between the area to be fractured and groundwater.
Very few countries have set specific rules on possible restrictions of HVHF activities according to Point 3.2 of the Recommendation. *Only the UK and Lithuania through the adoption of a legal text, have set specific restriction rules applying to HVHF.* *In the UK, according to the Infrastructure Act 2015, hydraulic fracturing is prohibited within protected groundwater source areas or other protected areas. The draft Onshore Hydraulic Fracturing (Protected Areas) Regulations 2015 define*

Articles 1 to 16 of Recommendation 2014/70/EU and the their general implementation by member states (taken from Sections 3 and 4 of the report by Milieu & Ricardo 2016-02)
such areas as areas of land at a depth of less than 1,200 metres beneath any land within 50 metres of an abstraction point or within or above a zone defined by a 50-day travel time for groundwater to reach a groundwater abstraction point, and areas of land at a depth of less than 1,200 metres beneath a National Park, the Broads, an area of outstanding natural beauty, or a World Heritage site respectively. New section 4A of the Petroleum Act 1998 (not yet in force) also provides that a well consent must now include a condition which prohibits associated hydraulic fracturing (= HVHF) from taking place in land at a depth of less than 1000 metres, and a condition which prohibits associated hydraulic fracturing from taking place in land at a depth of 1000 metres or more unless a hydraulic fracturing consent has been granted. *In Lithuania, exploration and/or production of unconventional hydrocarbon resources (such as shale gas) using HVHF is forbidden in groundwater protection zones and drinking water extraction zones.* *In the Netherlands, the SEA sets criteria to exclude a priori certain regions/areas from its future shale gas exploration activities or pay particular attention to these areas. The following surface areas are excluded from the SEA scenarios for future shale gas exploration activities: Protected areas such as Natura 2000 sites12; Drinking water catchment sites; Water protection areas such as sites for groundwater protection; Large surface water bodies; • Urban/residential areas. For the depth limitations, the SEA uses a depth limitation of 1,000 meters for horizontal drilling, including for groundwater areas. There is no specific distance limitation between groundwater and the fractured zone.* *In Germany certain federate laws set restrictions for fracking in specific areas (e.g. in water protection areas).The current federal legislation does not set such restriction of activities targeting specifically HVHF. However the draft law as of April 2015 contains some of these restrictions (e.g. prohibition of fracking activities in protected areas, setting of the minimum depth limitations of 3,000 metres) but not concerning all elements (e.g. no minimum distance between operations and residential areas required; no restrictions in flood prone or seismic prone areas). Several countries (e.g. Germany, Lithuania Poland, Romania) contain in their legislation restrictions similar to some of the ones set under Point 3.2 of the Recommendation but that apply to all types of activities (e.g. all activities restricted in flood prone areas) or to all hydrocarbon activities (e.g. prohibition of oil and gas operation in protected areas and near water sources). It is also common practice that such restrictions are set at the permitting level for each site on a case by case basis depending on whether the site falls within a protected area, flood prone area, seismic prone area or water protection area.* *Overall none of the countries covered include in their legislation all the restrictions set under Point 3.2 of the Recommendation.*
3.3. Member States should take the necessary measures to ensure that an environmental impact assessment is carried out on the basis of the requirements of Directive 2011/92/EU.
At Damme 3 site in Germany, no EIA was required. A screening was undertaken for the construction of the well pad but no screening was carried out for the entire site and HVHF activities. *In Poland, an EIA was carried out for three out of the five sites reviewed. A screening procedure with no EIA was applied at one site and neither a screening nor an EIA was carried out at the fifth site.* *In the UK, an EIA was carried out at the two post Recommendation sites (a screening without an EIA was carried out for the third site which pre-dates the Recommendation).* *In Spain from the sites selected, EIAs have been submitted to competent authorities by the operator in the "Sedano"14 and "Urraca"15 licenses. None of these EIAs have yet been approved by competent authorities. For the "Bezana" and "Bigüenzo" licenses, the authorities have only issued the EIA "scoping" decision at the time of writing this report.* *In Denmark when Total applied for the necessary permits to perform exploratory drilling at Vendsyssel-1, the Municipal Council in Frederikshavn decided subsequent to an EIA screening that a full EIA was required before any such permit could be granted. This EIA should only concern drilling without any use of hydraulic fracturing. Future exploratory drilling using fracturing would require a whole new EIA.* *In Romania, the EIAs only covered exploratory drilling without HVHF. A first screening procedure applied. In case of exploitation works, a new permitting procedure would be required as well as a new EIA.* *In Lithuania two EIA screenings were carried for specific project wells where hydraulic fracturing was planned but the competent authorities decided that an EIA in these two cases was not necessary.* *Even though not covered by the Recommendation, it is to be noted that in none of the countries is the scope of the EIA clearly defined in the law. In particular, it is unclear in the law whether the EIA has to cover one specific well project or several well projects in a license area or the whole license area. In Spain, for the Sedano license, one EIA covered three potential wells (Sedano 1, Sedano 2, Sedano 3) and where relevant it provided a specific analysis or assessment based on the characteristics of one potential drilling well area. For the Urraca license two EIAs were carried out: One covering the Urraca 1 proposed well site, and another covering Urraca 2 and 3 proposed well sites which are located very close to each other.* *In the countries covered, the scope of the EIA is decided on a case by case basis by the competent authorities.*
3.4. Member States should provide the public concerned with early and effective opportunities to participate in developing the strategy referred to in point 3.1 and the impact assessment referred to in point 3.3.
In countries where EIAs were completed or are being completed, the public participation procedures and EIA timeframes are significantly different from one country to another. *In all case studies it was however considered that the public had an early and effective opportunity to participate in the EIA procedure.* *In Poland, Spain and the UK, the EIAs covered the main characteristics of unconventional hydrocarbon exploration and the potential related impacts of HVHF (Further details are set in the national reports on the coverage of each EIA).* *Even though not covered by the Recommendation it is noteworthy that none of the countries covered under this study have adopted specific guidelines and/or rules on the content of the EIA for projects involving the production and production of hydrocarbons using HVHF. In Lithuania the two EIA screening decisions did not cover specific impacts related to hydraulic fracturing.*
4. EXPLORATION AND PRODUCTION PERMITS

Articles 1 to 16 of Recommendation 2014/70/EU and the their general implementation by member states (taken from Sections 3 and 4 of the report by Milieu & Ricardo 2016-02)
Member States should ensure that the conditions and the procedures for obtaining permits in accordance with applicable Union legislation are fully coordinated if: (a) more than one competent authority is responsible for the permit(s) needed; (b) more than one operator is involved; (c) more than one permit is needed for a specific project phase; (d) more than one permit is needed under national or Union legislation.
This principle on the coordination of the permitting procedure was met in all sites covered (for the exploration stage) with the exception of Romania where local authorities were not involved in the permitting procedure for the exploration wells
5. SELECTION OF THE EXPLORATION AND PRODUCTION SITE *5.1. Member States should take the necessary measures to ensure that the geological formation of a site is suitable for the exploration or production of hydrocarbons using high-volume hydraulic fracturing. They should ensure that operators carry out a characterisation and risk assessment of the potential site and surrounding surface and underground area.* *5.2. The risk assessment should be based on sufficient data to make it possible to characterise the potential exploration and production area and identify all potential exposure pathways. This would make it possible to assess the risk of leakage or migration of drilling fluids, hydraulic fracturing fluids, naturally occurring material, hydrocarbons and gases from the well or target formation as well as of induced seismicity.* *5.3. The risk assessment should:* *(a) be based on the best available techniques and take into account the relevant results of the information exchange between Member States, industries concerned and non-governmental organisations promoting environmental protection organised by the Commission;* *(b) anticipate the changing behaviour of the target formation, geological layers separating the reservoir from groundwater and existing wells or other manmade structures exposed to the high injection pressures used in high-volume hydraulic fracturing and the volumes of fluids injected;* *(c) respect a minimum vertical separation distance between the zone to be fractured and groundwater;* *(d) be updated during operations whenever new data are collected.* *5.4. A site should only be selected if the risk assessment conducted under points 5.1, 5.2 and 5.3 shows that the high-volume hydraulic fracturing will not result in a direct discharge of pollutants into groundwater and that no damage is caused to other activities around the installation.*
This principle could only be assessed for the exploration sites in Poland, the UK and to some extent Spain through information from the EIA documents. *In Poland this principle was partially reflected at the permitting level in the post- Recommendation sites with the exception of the dynamic modelling of impacts or the update of the risk assessment.* *In the UK, a qualitative environmental risk assessment is required as part of the environmental permit application, which addresses exposure pathways, although it is not directly linked to site selection. The requirements to mitigate the risk of seismicity is considered as an example of good practice within the risk assessment framework as it obliges operators to follow a set of detailed steps to demonstrate that the proposed development is satisfactory from a geological point of view.*
6. BASELINE STUDY *6.1. Before high-volume hydraulic fracturing operations start, Member States should ensure that:* *(a) the operator determines the environmental status (baseline) of the installation site and its surrounding surface and underground area potentially affected by the activities; (b) the baseline is appropriately described and reported to the competent authority before operations begin.* *6.2. A baseline should be determined for:* *(a) quality and flow characteristics of surface and ground water; (b) water quality at drinking water abstraction points;* *(c) air quality; (d) soil condition; (e) presence of methane and other volatile organic compounds in water; (f) seismicity;* *(g) land use; (h) biodiversity; (i) status of infrastructure and buildings; (j) existing wells and abandoned structures.*
Overall the parameters listed in the baseline study were well reflected at the examined sites with the exception of air quality, seismicity, the presence of methane and other volatile organic compounds in water, the status of infrastructure and buildings and existing wells and abandoned structures, which were not systematically assessed. *Although not covered under the Recommendation, it is noteworthy that the geographical scope of the baseline study and whether or not it is based on available data rather than on specific samples taken from the surrounding areas of the exploratory wells is not clearly defined in the law or permitting procedures of the countries covered. It is rather decided on a case by case basis between competent authorities and operators. It is also not always clear whether a baseline must be set before any operations and/or specifically before HVHF.* *In the UK, whereas this principle was not met for the site that pre-dates the Recommendation, for both post- Recommendation sites, baseline studies on air quality, archaeology/cultural heritage, greenhouse gases, community & socio-*

economics, ecology, hydrogeology & ground gases, induced seismicity, land-use, landscape & visual amenity, lighting, noise, resources & waste, transport, water resources and public health had to be carried out prior to the start of operations. They covered all aspects set in the Recommendation with the exception of the status of infrastructure and buildings, existing wells and abandoned structures22. It is to be noted that the UK asks for a baseline study on public health, which goes beyond the list of elements set in the Recommendation. It can be noted as an example of good practice that at the Preston Hall site it was planned to set groundwater monitoring boreholes around the edge of the well pad to set the baseline of the quality of groundwater prior operations close to the HVHF activities. It was also proposed in the permit to install surface network seismometers and seismometer array over an area of 2870 ha to collect baseline seismic data before HVHF occurs.

In Spain the decision of the competent authorities establishing the scope of the EIA23 also determines the content of the baseline study. It covers all the aspects mentioned in the Recommendation with the exception of the presence of methane and other VOCs in water, the status of infrastructure and buildings, existing wells and abandoned structures.

In Poland, a baseline study was carried out before operation/HVHF. The baseline area is defined on a case by case basis.

A description of the baseline is included in the environmental reports for three sites: Łeba and Łębork (post-date Recommendation) and Wejherowo (pre-Recommendation). The elements listed for the baseline are covered by the baseline study, with the exception of the presence of methane or other VOCs in water, air quality, seismicity and abandoned structures (depending on the sites). As part of the EIA procedure, the baseline description was reported to the competent authorities. Results of environmental monitoring for one site (Wejherowo license) had to be sent to the competent authorities. However, in the case of the other sites, the monitoring results conducted before the start of operations and after the EIA are not reported to the competent authorities. They are generally available in the operator's offices24 and are made available to the competent authorities upon request or during inspection. In the case of the pre-recommendation Lidzbark Warmiński site, the detailed information concerning the baseline study was unavailable and the baseline study covered only part of the listed environmental elements.

The geographical scope of the baseline differs from one country to another and from one site to another. For example in Spain, the EIA for Sedano 1,2, 3 submitted by operators refers to the ambient air quality baseline based on available data from air quality stations located between 40 km to 65 km away from the License, whereas for example, at the Zanowska site in Poland, air quality samples are taken within the site.

7. INSTALLATION DESIGN AND CONSTRUCTION

Member States should ensure that the installation is constructed in a way that prevents possible surface leaks and spills to soil, water or air.

8. INFRASTRUCTURE OF A PRODUCTION AREA

Member States should ensure that:

(a) operators or groups of operators apply an integrated approach to the development of a production area with the objective of preventing and reducing environmental and health impacts and risks, both for workers and the general public;

(b) adequate infrastructure requirements for servicing the installation are established before production begins. If an installation's primary purpose is producing oil using high-volume hydraulic fracturing, specific infrastructure that captures and transports associated natural gas should be installed.

9. OPERATIONAL REQUIREMENTS

9.1. Member States should ensure that operators use best available techniques taking into account the relevant results of the information exchange between Member States, industries concerned and non-governmental organisations promoting environmental protection organised by the Commission, as well as good industry practice to prevent, manage and reduce the impacts and risks associated with projects of exploration and production of hydrocarbons.

9.2. Member States should ensure that operators:

(a) develop project-specific water-management plans to ensure that water is used efficiently during the entire project. Operators should ensure the traceability of water flows. The water management plan should take into account seasonal variations in water availability and avoid using water sources under stress;

(b) develop transport management plans to minimise air emissions in general and the impacts on local communities and biodiversity in particular;

(c) capture gases for subsequent use, minimise flaring and avoid venting. In particular, operators should put in place measures to ensure that air emissions at the exploration and production stage are mitigated by capturing gas and its subsequent use. Venting of methane and other air pollutants should be limited to the most exceptional operational circumstances for safety reasons;

(d) carry out the high-volume fracturing process in a controlled manner and with appropriate pressure management with the objective to contain fractures within the reservoir and to avoid induced seismicity;

(e) ensure well integrity through well design, construction and integrity tests. The results of integrity tests should be reviewed by an independent and qualified third party to ensure the well's operational performance, and its environmental and health safety at all stages of project development and after well closure;

(f) develop risk management plans and the measures necessary to prevent and/or mitigate the impacts, and the measures necessary for response;

(g) stop operations and urgently take any necessary remedial action if there is a loss of well integrity or if pollutants are accidentally discharged into groundwater;

(h) immediately report to the competent authority in the event of any incident or accident affecting public health or the environment. The report should include the causes of the incident or accident, its consequences and remedial steps

taken. The baseline study required under points 6.1 and 6.2 should be used as a reference.

9.3. Member States should promote the responsible use of water resources in high-volume hydraulic fracturing.

10. USE OF CHEMICAL SUBSTANCES AND WATER IN HIGH-VOLUME HYDRAULIC FRACTURING

10.1. Member States should ensure that:

(a) manufacturers, importers and downstream users of chemical substances used in hydraulic fracturing refer to 'hydraulic fracturing' when complying with their obligations under Regulation (EC) No 1907/2006;

(b) using chemical substances in high-volume hydraulic fracturing is minimised;

(c) the ability to treat fluids that emerge at the surface after high-volume hydraulic fracturing is considered during the selection of the chemical substances to be used.

10.2. Member States should encourage operators to use fracturing techniques that minimise water consumption and waste streams and do not use hazardous chemical substances, wherever technically feasible and sound from a human health, environment and climate perspective.

11. MONITORING REQUIREMENTS

11.1. Member States should ensure that the operator regularly monitors the installation and the surrounding surface and underground area potentially affected by the operations during the exploration and production phase and in particular before, during and after high-volume hydraulic fracturing.

11.2. The baseline study required under points 6.1 and 6.2 should be used as a reference for subsequent monitoring.

11.3. In addition to environmental parameters determined in the baseline study, Member States should ensure that the operator monitors the following operational parameters:

(a) the precise composition of the fracturing fluid used for each well;

(b) the volume of water used for the fracturing of each well;

(c) the pressure applied during high-volume fracturing;

(d) the fluids that emerge at the surface following high-volume hydraulic fracturing: return rate, volumes, characteristics, quantities reused and/or treated for each well;

(e) air emissions of methane, other volatile organic compounds and other gases that are likely to have harmful effects on human health and/or the environment.

11.4. Member States should ensure that operators monitor the impacts of high-volume hydraulic fracturing on the integrity of wells and other manmade structures located in the surrounding surface and underground area potentially affected by the operations.

11.5. Member States should ensure that the monitoring results are reported to the competent authorities.

Monitoring measures were implemented at the sites were HVHF was carried out (Germany, Poland, the UK). In Spain, some monitoring measures are foreseen in the EIA documents drafted by the operators. No specific trends can be identified on the way the monitoring requirements were applied or planned to be applied at specific sites with the exception of the UK where post-recommendation sites, unlike pre-recommendation sites, apply specific monitoring measures reflecting the principle of the Recommendation (with the exception of the monitoring of the integrity of wells25 and other manmade structures in the surrounding area).

In Poland, at each site examined, monitoring of both the surface and underground area potentially affected was planned or carried out before and where relevant, after fracturing operations. Boundaries of monitoring area were defined on a case by case basis usually covering the drilling site and adjacent areas. In Poland, monitoring is based on the parameters set under the baseline study and refer to the baseline study in the selected sites where HVHF was carried out; with the exception of the seismicity monitoring which was only monitored at two sites (all of the sites are not located in seismic prone areas).. The well integrity and monitoring of impacts on manmade structures located in the surrounding surface and underground area potentially affected by the operations are carried out at the Wejherowo site (pre-dates Recommendation) and the Lębork sites (post-dates Recommendation) only. For the Wodynie Łuków site and Lidzbark Warmiński sites (pre-dates Recommendation) there is no information concerning the monitoring of manmade structures. For three of the sites (post-and pre- Recommendation) the obligation of reporting to the competent authorities of the monitoring results (for soil and groundwater only) is implemented.

In the UK, whereas the monitoring principles were not met for the site that pre-dates the Recommendation, for the sites that post-date the Recommendation, monitoring is to be carried under the terms of an Environmental Management and Monitoring Plan. The monitoring rules planned for these two sites are considered as an example of good practice (see table below).

Environmental Management and Monitoring Plan at Preston New Road and Roseacre Wood sites

Monitoring is to be carried out under the terms of an Environmental Management and Monitoring Plan (EMMP). The EMMP will be comprehensive in scope, and will cover baseline monitoring before operations, monitoring to be carried out during the drilling, fracturing and completion phases, and ongoing monitoring during production and post-abandonment. Monitoring would cover a range of environmental parameters including seismicity, ambient air quality around the site, noise levels, flowback fluid composition, surface water and groundwater composition and concentrations, ground gas composition and concentrations and fugitive gas emissions. Monitoring of the groundwater monitoring wells would continue following exploration well abandonment for a period agreed with the regulators, and subsequent decommissioning of the groundwater monitoring wells. The environmental permit requires sampling of groundwater and

surface water for 46 parameters at a minimum. In each case monitoring works were to cover a 4km radius of the proposed sites comprising the construction, operation and restoration of two seismic monitoring arrays comprising of 80 buried seismic monitoring stations and 10 (8 at Roseacre Wood) surface seismic monitoring states. The seismic monitoring stations would comprise underground installation of seismicity sensors, enclosed equipment and fenced enclosures. The surface array would also comprise monitoring cabinets. The applications were also for the drilling of three boreholes, each installed with two monitoring wells, to monitor groundwater and ground gas.

For these two sites all monitoring parameters of the Recommendation are covered with the exception of the "status of infrastructure and buildings" and "existing wells and abandoned structures". For these two sites no specific undertaking was identified in respect of monitoring the integrity of wells and other manmade structures in the surrounding area. However, under Regulation 13 of the Offshore Installations and Wells (Design and Construction) Regulations 1996, the well must be designed, constructed, operated, maintained and decommissioned in such a way that there is no unplanned release of fluids from the well so far as is reasonably practicable. The operator is required to provide a weekly report to HSE with details of the operations that week, the diameter and depth of the borehole and diameter and depth of the casing, and appoint an independent well examiner to ensure that regulatory requirements and industry standards are adhered to. When constructing the well, there is also a requirement to establish whether there are any nearby mine workings in which case the operator would need to consult with the Coal Authority and may require separate permission.

In Germany, based on available information, seismic monitoring of the Damme 3 well was carried out from the neighbouring well Damme 2. There is no information as to whether further elements were monitored at this site. Note that the German draft law package (not yet adopted) contains monitoring requirements for fracturing activities as well as for subsurface storage of flowback water.

12. ENVIRONMENTAL LIABILITY AND FINANCIAL GUARANTEE

12.1. Member States should apply the provisions on environmental liability to all activities taking place at an installation site including those that currently do not fall under the scope of Directive 2004/35/EC.

12.2. Member States should ensure that the operator provides a financial guarantee or equivalent covering the permit provisions and potential liabilities for environmental damage prior to the start of operations involving high-volume hydraulic fracturing.

13. ADMINISTRATIVE CAPACITY

13.1. Member States should ensure that the competent authorities have adequate human, technical and financial resources to carry out their duties.

13.2. Member States should prevent conflicts of interest between the regulatory function of competent authorities and their function relating to the economic development of the resources.

14. CLOSURE OBLIGATIONS

Member States should ensure that a survey is carried out after each installation's closure to compare the environmental status of the installation site and its surrounding surface and underground area potentially affected by the activities with the status prior to the start of operations as defined in the baseline study.

15. DISSEMINATION OF INFORMATION

Member States should ensure that:

(a) the operator publicly disseminates information on the chemical substances and volumes of water that are intended to be used and are finally used for the high-volume hydraulic fracturing of each well. This information should list the names and Chemical Abstracts Service (CAS) numbers of all substances and include a safety data sheet, if available, and the substance's maximum concentration in the fracturing fluid;

(b) the competent authorities should publish the following information on a publicly-accessible internet site within 6 months of this Recommendation's publication and in intervals of no longer than 12 months:

(i) the number of wells completed and planned projects involving high-volume hydraulic fracturing;

(ii) the number of permits granted, the names of operators involved and the permit conditions;

(iii) the baseline study produced under points 6.1 and 6.2 and the monitoring results produced under points 11.1, 11.2 and 11.3(b) to (e);

(c) the competent authorities should also inform the public of the following without undue delay.

(i) incidents and accidents under point 9.2(f);

(ii) the results of inspections, non-compliance and sanctions.

The principle on dissemination of information either by operators or by competent authorities is not adequately reflected either within legislation, at the permitting level or on a voluntary basis in the countries covered under this study as outlined in the paragraphs below. In several countries due to the lack of (planned) HVHF activities, this principle is not always applicable. In fact this principle could only be assessed entirely in Germany, Poland and the UK.

In none of the countries covered is there a specific legal obligation to ensure that operators disseminate information on fracturing fluids. The only exception is the draft legislation in Germany (not yet adopted) that includes disclosure obligations concerning fracturing substances. In several countries such information is provided in practice but does not reflect all the specific points set in the Recommendation. For example, in none of the examined countries were safety data sheets disseminated by operators.

Articles 1 to 16 of Recommendation 2014/70/EU and the their general implementation by member states (taken from Sections 3 and 4 of the report by Milieu & Ricardo 2016-02)
In Spain, as part of the permitting procedure, EIA decisions require operators to provide information on the fracturing fluids including the concentration levels or quantities of the components. The operators have made available on their websites the EIA documents that contain information on the fracturing fluids planned to be used. For example the EIA prepared by operators on the Sedano licence provides the composition of the fluid, the function of each of its elements and the concentration in percentage. However it does not include information on related safety data sheets and CAS number of substances planned to be used.
In Germany at the Damme 3 site, fracturing substances were not disclosed prior to their use. Around 2010, when the public discussion on the environmental side effects of fracking grew, companies, but also the mining authorities, started publishing more detailed information on their websites, including information on the chemicals used. For instance, ExxonMobil published information27 on chemicals used for fracking including well specification, date, number of fracks, quantities of used fluids and chemicals, CAS- numbers, and concentration in fracking fluid. Safety data sheets were not included. The table below shows in details how chemicals used at Damme 3 were disclosed by Exxon Mobil.
In Poland an illustrative composition of the fracturing fluid and water consumption which may be used is provided in environmental reports before use (with the exception of Wodynie-Lukow and Lidzbark where no information is available prior to use). This illustrative composition does not always specify the exact list of chemicals that will be used.
The information about the composition of the fracturing fluid after use is provided by the operators on their website. There is also an obligation for reporting of the composition and amount of fracturing fluid and flowback fluid to the Mining Office after use. Beyond the disclosure of chemicals used, the licenses were also available at operators' websites for all sites (except the Lidzbark Warmiński sites where the operator is experiencing changes of name and owners). The environmental decisions were available for the Wejherowo and Łeba sites but not for the other sites.
In the UK, the principles of the Recommendation are not fully met for the Preese Hall site. While the operator has published information on the chemical substances used at the site but not before use, it does not refer to the specific substances or CAS numbers of each substance. Information on volumes of water that were used is not disclosed on the operators' website and this information is not available from the planning documentation reviewed.
For the Preston New Road and Roseacre Wood sites, the principles of the Recommendation are not met as the operator only lists information on the chemical substances used at another site (the Preese Hall site) as an illustrative example in the permit applications. Information on volumes of water that are intended to be used is not disclosed on the operators' website. Information on the substances to be used is available as part of the permit application, which states that the hydraulic fracturing fluid will comprise mainly water, a friction reducer and may include diluted hydrochloric acid < 10% but does not provide the CAS number or safety data sheet or the name of the friction reducer.
In Denmark, only drilling was planned and carried out (no HVHF). On the website for Vendsyssel-1, Total lists the following substances, which they intended to use for the exploratory drilling: bentonite; soda ash; potassium chloride; potassium bicarbonate; citric acid; chalk; and conventional salt.
In Hungary, there is no information available on the operators' websites (e.g. Falcon or Exxon Mobil) related to chemical substances and volume of water used in low volume hydraulic fracturing.
In Lithuania no information was provided by operators of the two exploratory wells where low hydraulic fracturing was carried out.
In Romania, it could not be verified at this date whether the operator published information on drilling fluids, because due to the decision of definitively withdrawing from Romania, Chevron closed up its website and any other office.
In Germany, permitting documents are not publically available. LBEG did not carry out any specific dissemination activities related to HVHF permits in relation to the Damme 3 site. Brief information specifying the well name (but without well or fracking details) was published in the annual reports as for any other new permits.
In Denmark, pursuant to available information, there have been in the past (before the adoption of the Recommendation) two to three instances where HVHF may have been used. Such information is not publicly accessible on a Competent Authority website.
In Hungary, no HVHF has been carried out. Competent authorities do not disclose information mentioned in Point 15 of the Commission Recommendation on their websites related to oil and gas exploration/extraction projects involving low volume hydraulic fracturing.
In Lithuania, no information as mentioned under principle 15 of the Recommendation on the two shale gas exploratory developments that occurred in Lithuania under the Rietavas and Gargždai license areas were available on the competent authority website.
The distribution of competences between the State and the Autonomous Regions in Spain28 result in a lack of a centralised source of information covering information listed in principle 15 of the Recommendation for all projects across Spain. For those projects falling under the competence of the State, the MAGRAMA has an online research engine in which the relevant documentation (i.e. EIA documentation and in some cases, the licenses and permits) can be accessed and which shows the timeline of the proceedings29. The Recommendation establishes that the information should be updated.
in intervals no longer than 12 months. The interviewed authorities30 indicated, however, that the information available in the referred engine might not be totally up to date. The Hydrocarbons Technical Archive of the MINETUR31 also provides information on the status of the proceedings both for State and Autonomous region projects. However, the website does not include any documentation. For Autonomous regions, there is no electronic format database. The documentation can be requested from the competent department in charge of environmental matters. This approach is therefore not in line with the Recommendation, which requires information to the published on the internet.
In Poland, the Ministry of the Environment maintains a special website32 providing information about licenses and wells (the number of wells completed and planned projects involving high-volume hydraulic fracturing, license issue date, area of the license, expired time, counties covered by the license). However, information is not available concerning all environmental permits or more detailed data like monitoring results, baseline study or accidents/incidents and inspection results.
In Romania, details of environmental permits / approvals / consents granted are publicly accessible on the public registers of the Environmental Protection Agencies. NAMR publishes a map showing the areas of all current prospecting, exploratory, development and exploitation activities in Romania. Baseline studies are publicly available on the EPA website, while monitoring results are not but can be consulted on request.
In the UK, for the site that pre-dates the publication of the Recommendation, planning documentation for the Preese Hall site is publicly available on the website of Lancashire County Council. To date, there is no central registry of the

Articles 1 to 16 of Recommendation 2014/70/EU and the their general implementation by member states (taken from Sections 3 and 4 of the report by Milieu & Ricardo 2016-02)	
wells completed or planned projects involving HVHF in the UK. However, details of environmental permits granted are publicly accessibly on the public registers of the EA, SEPA and the NIEA. Applications for an environmental permit, along with any supporting documentation, are available on the EA's website. Details of incidents and accidents reported to HSE are not publicly available nor are they available on request, although details of formal enforcement action are publicly available Details of non-compliance with an environmental permit are available of the public registers of the EA, SEPA and the NIEA. *In Portugal, the website of ENMC includes information on the exploration and production of hydrocarbons by unconventional methods based on the principles of the Recommendation, namely the number of wells involving high fracturing methods (none), number of permits granted (none) and information on baseline studies carried out (none).* *16. REVIEW* *16.1. Member States having chosen to explore or exploit hydrocarbons using high-volume hydraulic fracturing are invited to give effect to the minimum principles set out in this Recommendation by 28 July 2014 and to annually inform the Commission about the measures they put in place in response to this Recommendation, and for the first time, by December 2014.* *16.2. The Commission will closely monitor the Recommendation's application by comparing the situation in Member States in a publicly available scoreboard.* *16.3. The Commission will review the Recommendation's effectiveness 18 months after its publication.* *16.4. The review will include an assessment of the Recommendation's application, will consider the progress of the best available techniques information exchange and the application of the relevant BAT reference documents, as well as any need for updating the Recommendation's provisions. The Commission will decide whether it is necessary to put forward legislative proposals with legally-binding provisions on the exploration and production of hydrocarbons using high-volume hydraulic fracturing.*	
Directive 2010/75/EU (IED)	*In Denmark, in the case of an application for commercial exploitation of oil and gas resources, the transposing legislation of the IED comes into play and no specific volume thresholds are set out in Danish law. No environmental permit is however required for exploratory drilling.* *In Poland, the activities concerned at all sites covered by the case studies are not subject to the national law transposing the IED provisions. Gas combustion in flares is defined as a diffuse emission and does not require an air emission permit. Emissions may be subject to environmental fees.* *In Spain, no information was available on whether the competent authorities plan to apply this Directive to shale gas developments. However, the Royal Decree 815/2013, which transposes Directive 2010/75/EU and adapts Law 16/2002 to the requirements of the Directive, does not specifically cover activities of extractive industries.* *The application of the IED has been considered for both the Preston New Road and Roseacre Wood sites in the UK. For each, the IED applies to the proposed incineration by flaring of hazardous waste, namely natural gas above 10 tonnes per day, as an activity listed in schedule 1 of the Environmental Permitting (England and Wales) Regulations 2010.* *This differs from the situation in Scotland, where the IED is not applied until the activity of refining is carried out. The flaring of gases is therefore not treated as the incineration of waste under the national legislation transposing the IED. Where an activity under Schedule 1 of the Pollution Prevention and Control (Scotland) Regulations 2012 is being carried out (this includes refining activities), any flaring or venting within the site boundary can be regulated as a 'directly associated activity'. However Scotland considers that no such activities are carried out during the exploratory phase (HVHF is not listed as an activity under Annex I of the IED), and consequently that the flaring of gases is not regulated and therefore would not require a permit.* *In Romania, the law on industrial emissions transposing the IED does not apply to the oil and gas production sector and the relevant environmental documents at the Pungesti site do not mention it either.*
Directive 2006/21/EC - (Extractive Waste Directive)	*Extractive waste definition* *In Poland, according to permitting practice, as a result of the HVHF processes, the following extractive waste arises: Drilling cuttings and mud, Flowback, Solid part of the flowback. Gas produced during the exploration stage and oil recycled from the flowback was not classified as extractive waste. Gas was flared and oil was sold to a refinery. Hydraulic fracturing residues remaining in the underground after fracturing were not classified as waste. No information could be found on their status.* *In Spain, the current EIA documents prepared by operators mention how non-extractive waste and extractive waste will be managed. They include as extractive waste the flowback water and the gravel (ripios) and mud (lodos) from the drilling well to be collected and stored on-site and transferred to treatment facilities for their appropriate management. They however do not consider the residues of fracturing fluids remaining underground as extractive waste.* *IN the UK, at the Preston New Road and Roseacre Wood sites (England), extractive waste included drill cuttings, flow-back fluid, natural gas, scale, cement, spacer fluid and hydraulic fracturing fluid remaining in the formation after fracturing. In Scotland and Northern Ireland, the production of 'flowback' fluid from hydraulic fracturing will be treated as an extractive waste activity and therefore will be required to have a waste management plan in place, to demonstrate to the planning authorities that the requirements of the Extractive waste Directive are met.* *In Germany, according to a study carried out on behalf of the Federal Environmental Agency in 201233, handling of flowback is subject to requirements under legislation on extractive waste and on wastewater. Where the residues are radioactive, sludge and deposits fall under legislation on radiation protection, except where compliance with legally defined monitoring limits is assured. Flowback is both liquid extractive waste and wastewater, since flowback – recovered water – contains both (unaffected) formation water and injected water that has been affected via human use through the*

	addition of additives, injection, mixing with formation water and extraction. *No information was available and/or no position stated from the competent authorities from the other countries covered under this study.* *Waste facility* *In the UK (England and Wales), following receipt of guidance from the Commission in December 2011, to the effect that flowback fluid from HVHF should be considered under the Extractive waste Directive, the regulatory position statement was changed, and any new activities were required to obtain a permit under the Extractive waste Directive. This approach has been applied at the Preston New Road and Roseacre wood sites. In each case the EA permit covers the management of extractive waste and includes a below- ground non-hazardous waste facility (the accumulation of injected hydraulic fracturing fluid which will remain in the underground target formation and has become waste) and an above-ground hazardous waste facility (the temporary deposit and accumulation of hazardous drill cuttings coated with residual Low Toxicity Oil Based Muds (LTOBM), hazardous scale and hazardous spacer fluid in storage containers, and which can be carried out on the site).* *In Poland, none of the examined sites were considered by permitting authorities to include any "waste facilities" as defined under the Extractive Waste Directive. Remaining underground structures are not considered as a waste facility, either as it is considered in Poland that residues of hydraulic fracturing are not extractive waste.* *In Spain, the current EIA documents prepared by operators do not mention that the remaining underground structure will be considered as a waste facility.* *No information was available and/or no position stated from the competent authorities from the other countries covered under this study.* *Extractive waste legislation applied to underground injection of waste for disposal* *In Poland, in the case studies assessed, the extractive waste legislation was not applied to the underground injection of waste for disposal. In one of the case studies, part of the flowback was injected underground into a depleted gas deposit at a different site.* *In Spain, underground injection of waste for disposal is not foreseen in the environmental documents submitted by the operator for the sites assessed.* *In the UK, no underground injection of flowback water for disposal has been carried out. However according to competent authorities, since hydraulic fracturing fluids remaining in the underground are considered extractive waste, the extractive waste legislation would also apply in such situation.* *No information was available and/or no position stated from the competent authorities from the other countries covered under this study.*
Directive 2000/60/EC - (Water Framework Directive)	*In Germany the proposed law mentions that the injected fluid must be classified as non- hazardous to water (in case of fracking activities) or as low hazardous to water (in case of flowback and produced water coming out of the well and injected underground for disposal).* *In Hungary, the competent authorities consider that HVHF would need a permit in view of Article 11(3)(j) of the Water Framework Directive. In case of HVHF, the competent authorities will determine a minimum protection zone between the groundwater bodies and the fracturing zone. The activity shall be carried out under controlled conditions, including the establishment and operation of a monitoring network and data supply including the integrity of wells and the changes of the underground fracture network.* *In Poland, in the sites covered by the study, it was considered by permitting authorities that the geological and hydrological structure of the license areas would ensure sufficient protection of the groundwater. It is therefore considered that hydraulic fracturing products are not injected into groundwater at any of the considered sites. Therefore the exemption related to the prohibition of direct discharges of pollutants into groundwater was not deemed necessary at the examined sites.* *In Spain, according to operators' information for all the sites selected, there are no foreseeable impacts in aquifers, so such authorisation would not be required either. No further information on the competent authorities' point of view on the interpretation of the application of this EU requirement was available.* *At UK selected sites, as there were not to be any direct discharges to groundwater at any of the sites reviewed, the operator in each case has not had to rely on the exemption under Article 11(3)(j) of the Water Framework Directive . At the Preese hall site, prior to restoration work commencing on site, the applicant was to provide the EA with additional information to identify any fluids remaining either within the vertical well bore or within the rocks from the fracturing process, together with a risk assessment to confirm that any such fluids do not present a risk to any groundwater. The information submitted was to include details of any potential processes which could result in fluids discharging into a groundwater bearing strata. The EA has confirmed that as part of the decommissioning process (in which the HSE was also involved) the operator provided this information, together with a risk assessment to confirm that any such fluids would not present a risk to groundwater.* *In Scotland in relation to the injection of the fracturing fluid, the available SEPA guidance states that this must meet the appropriate exemption under the Water Framework Directive. Article 11(3)(j) of the Water Framework Directive prohibits the direct discharge of pollutants into groundwater, subject to certain exemptions (not specified). SEPA considers that existing guidance by Commission services does not discuss the applicability of Article 11(3) (j) with respect to the initial injection of fracking fluid or the re-use of flowback as an injection fluid in fracturing operations, rather than for disposal.*

Articles 1 to 16 of Recommendation 2014/70/EU and the their general implementation by member states (taken from Sections 3 and 4 of the report by Milieu & Ricardo 2016-02)	
	No information was available and/or no position stated from the other countries covered under this study.

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