Project Acronym and Title:

M4ShaleGas - Measuring, monitoring, mitigating and managing the environmental impact of shale gas

INTEGRATED BEST PRACTICES AND RECOMMENDATIONS FOR MINIMISING THE ENVIRONMENTAL FOOTPRINT OF SURFACE SHALE GAS OPERATIONS

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Public introduction

M4ShaleGas stands for Measuring, monitoring, mitigating and managing the environmental impact of shale gas and is funded by the European Union's Horizon 2020 Research and Innovation Programme.
The main goal of the M4ShaleGas project is to study and evaluate potential risks and impacts of shale gas exploration and exploitation. The focus lies on four main areas of potential impact: the subsurface, the surface, the atmosphere, and social impacts.
The European Commission's Energy Roadmap 2050 identifies gas as a critical fuel for the transformation of the energy system in the direction of lower CO_2 emissions and more renewable energy. Shale gas may contribute to this transformation.
Shale gas is – by definition – a natural gas found trapped in shale, a fine grained sedimentary rock composed of mud. There are several concerns related to shale gas exploration and production, many of them being associated with hydraulic fracturing operations that are performed to stimulate gas flow in the shales. Potential risks and concerns include for example the fate of chemical compounds in the used hydraulic fracturing and drilling fluids and their potential impact on shallow groundwater. The fracturing process may also induce small magnitude earthquakes. There is also an ongoing debate on greenhouse gas emissions of shale gas (CO_2 and methane) and its energy efficiency compared to other energy sources
There is a strong need for a better European knowledge base on shale gas operations and their environmental impacts particularly, if shale gas shall play a role in Europe's energy mix in the coming decennia. M4ShaleGas' main goal is to build such a knowledge base, including an inventory of best practices that minimise risks and impacts of shale gas exploration and production in Europe, as well as best practices for public engagement.
The M4ShaleGas project is carried out by 18 European research institutions and is coordinated by TNO-Netherlands Organization for Applied Scientific Research.

Executive Report Summary

The exploration and exploitation of unconventional hydrocarbon deposits, like any other mining activity, may pose a potential hazard to the environment. The most sensitive elements of the environment are water, both surface and underground, the surface of the terrain (soil), as well as the atmosphere. We should also not forget about changes in the landscape, increased heavy traffic of cars or noise, which have a negative impact on the quality of life of people near the well pad. However, most of these impacts are of short-term duration and can be minimised by e. g. installation of soundproof screens, use of low-emission equipment and isolation of the terrain surface. The correct construction of the wells, especially effective insulation of water-bearing levels, prevents water contamination. On the other hand, proper surface protection and remediation of the area makes it possible to fully restore its original character and development method. However, it cannot be excluded that emergencies may occur during such work, e. g. failure of the equipment or not following procedures. With a view to potential environmental risks, it is necessary to monitor them during shale gas operations.
This report collects and briefly summarizes the work of six scientific teams engaged in studying the impact of surface operations related to shale gas exploration and exploitation on natural environment elements: groundwater, surface water, soil, waste management, well site infrastructure and transport. The report presents best practices and recommendations for minimising the environmental footprint of surface shale gas operations, based on the results of a study carried out within the M4ShaleGas project. Recommendations are based on literature reviews of current practices in the USA, Canada and Europe as well as dedicated experimental and modelling studies. The first part of the report presents detailed recommendations prepared by particular research groups implementing the SP2 task. Recommendations gathered in this part of the report were integrated and divided by the editors of the report into four areas i.e. 1) environmental monitoring, 2) sustainable management of water, 3) liquid waste management and 4) well site infrastructure and transport. The second part of the report, based on the conducted analysis, presents general best practices and recommendations for minimising the environmental footprint of surface shale gas operations. Applying best practices and recommendations developed as part of the SP2 task should contribute to increasing environmental safety as well as reducing concerns among local communities.

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1 INTRODUCTION

1.1 Context of M4ShaleGas

Shale gas source rocks are widely distributed around the world and many countries have now started to investigate their shale gas potential. Some argue that shale gas has already proved to be a game changer in the U.S. energy market (EIA 2015[1]). The European Commission's Energy Roadmap 2050 identifies gas as a critical energy source for the transformation of the energy system to a system with lower CO_2 emissions that combines gas with increasing contributions of renewable energy and increasing energy efficiency. It may be argued that in Europe, natural gas replacing coal and oil will contribute to emissions reduction on the short and medium terms.

There are, however, several concerns related to shale gas exploration and production, many of them being associated with the process of hydraulic fracturing. There is also a debate on the greenhouse gas emissions of shale gas (CO_2 and methane) and its energy return on investment compared to other energy sources. Questions are raised about the specific environmental footprint of shale gas in Europe as a whole as well as in individual Member States. Shale gas basins are unevenly distributed among the European Member States and are not restricted within national borders, which makes close cooperation between the involved Member States essential. There is relatively little knowledge on the footprint in regions with a variety of geological and geopolitical settings as are present in Europe. Concerns and risks are clustered in the following four areas: subsurface, surface, atmosphere and society. As the European continent is densely populated, it is most certainly of vital importance to understand public perceptions of shale gas and for European publics to be fully engaged in the debate about its potential development.

Accordingly, Europe has a strong need for a comprehensive knowledge base on potential environmental, societal and economic consequences of shale gas exploration and exploitation. Knowledge needs to be science-based, needs to be developed by research institutes with a strong track record in shale gas studies, and needs to cover the different attitudes and approaches to shale gas exploration and exploitation in Europe. The M4ShaleGas project is seeking to provide such a scientific knowledge base, integrating the scientific outcome of 18 research institutes across Europe. It addresses the issues raised in the Horizon 2020 call LCE 16 – 2014 on *Understanding, preventing and mitigating the potential environmental risks and impacts of shale gas exploration and exploitation.*

[1] EIA (2015). Annual Energy Outlook 2015 with projections to 2040. U.S. Energy Information Administration (*www.eia.gov*).

1.2 Study objectives for this report

The main objective of this report is to present best practices and recommendations in area of environmental monitoring, sustainable management of water, liquid waste management and well site infrastructure and transport during surface shale gas operations in Europe.

The presented report is, in the first part, a collection and summary of the recommendations contained in six 2-page factsheets (developed by the research teams implementing the project M4ShaleGas) with information about minimising the environmental footprint of surface shale gas operations:

1. Recommendations on environmental monitoring (D7.4)
   by M. Konieczyńska, O. Lipińska (PGI-NRI)
2. Recommendations on risk assessment of impacts on groundwater quantity and quality (D8.5)
   by O.S. Jacobsen, A.R. Johnsen, P. Gravesen, N.H. Schovsbo, J.B. Kidmose (GEUS)
3. Recommendations for the sustainable management of water in shale gas operations in Europe (D9.4)
   by L. Vadillo-Fernández, V. Rodríguez Gómez, F. J. Fernández-Naranjo (IGME)
4. Recommendations for liquid waste management in shale gas operations (D10.4)
   by E. Kukulska-Zając, A. Król, M. Gajec (INiG-NRI)
5. Recommendations on flowback water composition (D11.4)
   by A. Vieth-Hillebrand, F.D.H. Wilke, M. Kühn (GFZ), J. Francu (Czech Geological Survey)
6. Recommendations on well site infrastructure and transport (D12.5)
   by F. Worrall, S.A. Clancy (Durham Univ.), P. Goodman, N. Thorpe (Newcastle Univ.)

The summary presents general best practices and recommendations for minimising the environmental footprint of surface shale gas operations.

1.3 Aims of this report

The aim of this report is to present an integrated best practices and recommendations for minimising the environmental footprint of surface shale gas operations in Europe, prepared on the basis of the results of research carried out under the M4ShaleGas project. The detailed recommendations presented here are recommendations prepared by individual research groups implementing the M4ShaleGas project and are available on the project website (http://www.m4shalegas.eu).

2 RECOMMENDATIONS FOR MINIMISING THE ENVIRONMENTAL FOOTPRINT OF SURFACE SHALE GAS OPERATIONS – DATA FROM FACTSHEETS

The following section collects and presents the best practices and recommendations developed by the different research groups within SP2, best practices and recommendations for minimising the environmental footprint of surface shale gas operations in Europe. The best practices and recommendations presented in this chapter are integrated and divided into four areas: environmental monitoring, sustainable management of water, liquid waste management and well site infrastructure and transport. This way of presenting results ensures greater transparency and avoids duplication of the same recommendations.

2.1 Recommendations on environmental monitoring (*based on Report D7.4*)

Exploration and exploitation of unconventional hydrocarbon deposits requires a broad, individual and comprehensive environmental approach. This is related to e. g. the fact that this type of work is relatively new and poorly understood in Europe. In such a situation, monitoring of the environment seems to be a necessity which will undoubtedly contribute to increasing the safety of the natural environment and human health.

At European level, the basic guidelines for environmental monitoring are regulated by directives, such as the Water Framework Directive or the Groundwater Directive. Nevertheless, there are still differences between EU countries in terms of objectives, measurement methods and performance reporting.

As part of the M4ShaleGas project, detailed recommendations on environmental monitoring were developed (*Konieczyńska and Lipińska, Report D7.4, 2017*):

- Dedicated environmental monitoring for shale gas development is a need. In an early exploration and production stage in Europe it should be prepared and conducted for particular well pads chosen as representative for a location. In next phase, when more well pads operate, the monitoring program should cover a group of well pads located within the same location (where as location an area characterized by similar geological and hydrogeological conditions and land-use patterns is considered).
- Monitoring scope and network must be planned with regard to local current and historical land use, geological and hydrogeological conditions, ecosystems needs as well as to specific features of used well drilling and completion technology. Future observations must be compared with baseline assessment results obtained prior to any shale gas activities.
- Monitoring needs to cover the entire life-time of shale gas operations, with baseline state measurements, observations of boreholes drilling & completion activities and their direct impact on surroundings (noise levels, emissions and air quality, spills and accidents and effects on soil and water quality), long term

survey during production period and post closure observations. The monitoring scope, frequencies and focus in each phase can be different.

- Monitoring must be conducted up to certain time after decommission of wells.
- Monitoring system has to enable detection of changes in quality of soils and fresh water (both surface and groundwater), identification of such changes causes mechanisms and launch of quick and proper remedy actions.
- Monitoring of deeper saline aquifers should aim in early warning of induced fugitive migration of fluids and/or gases from deep geological strata towards the fresh water zone and land surface.
- A soil gas observation network in direct vicinity of working or decommissioned boreholes as well as other well defined potential migration pathways (such as known fault zones, old deep mine shafts) should be established for detection of gas migration towards land surface along casing or other artificial or natural paths. Isotopic ratio analyses of soil gas constituents (e.g. hydrogen and carbon isotopes in methane) need to be implemented for a better interpretation of observations results (especially gas source identification).
- All baseline results, technological details with regard to types and quantities of substances used in shale gas operations as well as subsequent monitoring observations results should be stored in publicly available databases.
- Environmental monitoring ought to be conducted by independent institutions but financed by shale gas operators.
- Additional environmental monitoring might be necessary around waste facilities and treatment installations to observe potential impact of waste generated by shale gas activities.

2.2 Recommendations for the sustainable management of water (*based on Report D8.5 and D9.4*)

Proper management of water resources during exploration and exploitation of unconventional hydrocarbons is very important. This is due to the fact that this type of work can affect both quantity and quality of the water resources. As a result of leaks, accidents or failure to comply with the applicable safety procedures, groundwater can be contaminated with the components of the gas itself or with substances derived from fracturing fluids or flowback and produced water. In addition, the need to use large amounts of water may also contribute to a reduction in groundwater resources, which will have an impact on drinking water sources, agriculture, industry, etc. In such a situation, all the water cycle must be controlled and whatever risk assessment analysis must consider it in a comprehensive manner.

The implementation of the M4ShaleGas project allowed to develop guidelines concerning the sustainable management of water and risk assessment of impacts on groundwater quantity and quality (*Jacobsen et al., Report D8.5, 2017; Vadillo-Fernández et al., Report D9.4, 2017*):

- Accomplishment by the operators of a Water Management Plan (based on a complete hydrogeological assessment) for each specific play to control effectively the entire water cycle. Aspects as the availability of freshwater and information about the total volume and composition of the water and liquid waste in every part of the water cycle, must be included. In addition, the determination of tracers to perform the monitoring must be assessed in this Plan.

- Follow the hierarchy principle of the Waste Framework Directive and the guidelines of the Water Framework Directive regarding water acquisition: minimising the total volume of water is a best practice. In parallel with this, reusing flowback for subsequent fracturing operations and using alternative sources (treated wastewater from municipal treatment plants and brackish water are conductive for this purpose) would be also best practices. Sharing sources of water with other operators could help to save water resources.
- Reduce of the use of chemicals from the operators and use of non-hazardous chemicals wherever possible.
- Protect storage sites with impermeable liners or even to construct a watertight compartment, with enough volume to retain whatever accidental spill.
- Store liquid waste in tanks (provided with closed-loop systems). Store chemicals, fracturing fluids and liquid waste away from surface waters, aquifers and other sensitive areas, determining buffer zones after a case-by-case examination.
- Water acquisitions for hydraulic fracturing over time and in areas of low water availability. The baseline study should as a minimum include groundwater flow properties and its chemical composition. Monitoring design must be based on a priori local characterization of the hydrological and hydrogeological conditions. Characterization and monitoring must be organized according to: 1) Improve knowledge and understanding of the local area. 2) Documenting this understanding by observations. 3) Be able to conduct remediation of inappropriate influences.
- Spills during handling of hydraulic fracturing liquids and additives. Spills of produced water during the handling stage have reached groundwater and surface water resources in some cases. The lack of information of the composition of chemicals in fracturing fluids, and the fate and transport of spilled fluids greatly limits the ability to evaluate the potential impacts to surface water and groundwater resources. Spill prevention plans and response activities might prevent spilled fluids from reaching groundwater or surface water and minimise impacts from spilled fluids.
- In order to predict impact from spills or accidents baseline monitoring data and field studies of hydrogeological properties of the areas in question are needed.
- Avoid injection of hydraulic fracturing fluids which could leak directly into groundwater aquifers. Migration via leaks in old or abandoned deep wells is the most likely pathway that could permit injected chemicals and dissolved compounds from the shales from depth to contaminate shallower aquifers. Only minor possibilities exist for hydraulic fracturing to create subsurface pathways that could permit contamination of shallower aquifers from injected chemicals and dissolved compounds from the deep shales.
- Discharge of inadequately treated hydraulic fracturing liquid waste to surface water should be avoided in any case. Disposal or storage of hydraulic fracturing

liquid waste in unlined pits, resulting in contamination of groundwater must not take place.

- Administrative entities should consider the application of the Directive 2001/42/EC on the assessment of the effects of certain plans and programs on the environment ("SEA Directive") to shale gas operations, since it is the most effective approach to address cumulative impacts at national and European level.

2.3 Recommendations for liquid waste management (*based on Report D10.4 and D11.4*)

Proper management of waste generated during shale gas operations is a crucial issue while considering safety of natural environment, mainly due to the fact that these are new, hardly recognized wastes in Europe. Liquid waste (flowback and produced water) from shale gas operations is not inert waste. They may contain both substances derived from process fluids used for fracturing as well as substances washed out of rocks during the drilling process. Additionally, in Europe there are currently no legal regulations particularly dedicated to the management of flowback and produced water from the exploration and exploitation of unconventional hydrocarbons.

In such a situation, the guidelines developed as part of the project for the management of liquid waste generated during shale gas operations may contribute to reducing public concerns. The guidelines are (*Kukulska-Zając et al., Report D10.4, 2017; Vieth-Hillebrand et al., Report D11.4, 2017*):

- Supplement the existing legislation with requirements on how to handle waste such as flowback and produced water, including uniform requirements for testing/characterization of this waste.
- Supplement the List of Waste with a new type of waste (i. e. flowback and produced water) with codes suitable for both hazardous and non-hazardous waste.
- It is important not to classify flowback water as a wastewater, since as such, it cannot be reused for hydraulic fracturing or injected underground as disposal option in accordance with current legislation.
- Disclosure for public, more broadly than before, data on the composition (quantitative and qualitative) of the technological fluids used during shale gas operations and information on the composition and properties of the waste generated, as well as information on how to further manage the waste. Data on the final management of waste would be valuable information for local communities and would also facilitate control in the correct application of procedures for the further management of waste authorised for this control body.
- Full disclosure of the applied chemicals for hydraulic fracking is necessary for risk assessment. Only with knowledge of the compounds that are injected into the reservoir, it will be feasible to assess the possibility of subsurface reactions in the shale formation and make assumptions about flowback and produced water compositions.

- Collecting and keeping data on the composition (quantitative and qualitative) of technological fluids and waste. Storage of this type of information will allow us to make a clear statement whether possible environmental pollution, occurring even after time, is related to shale gas operations.
- Recommended basic scope of determinations for testing physicochemical characteristics of flowback and produced water for potential environmental impact should include: pH, specific conductance, total dissolved solids (TDS), dry residue, total organic carbon (TOC), chemical oxygen demand (COD), metals (including heavy metals), inorganic anions, hydrocarbons (including mono- and polycyclic aromatic hydrocarbons), phenol index, ammonia nitrogen or total nitrogen, anionic surfactants, substances extractable with petroleum ether or chloroform and alcohols. Knowledge of the flowback and produced water composition will enable selection of the appropriate waste treatment method and/or informative decision on further disposal or storage of the waste.
- Develop a flowback and produced water sampling procedure for laboratory testing and guidance on analytical methods dedicated to the determination of individual substances and components in these fluids with very complex matrix. Testing of such samples should not involve methods routinely used for testing water quality. Improvements in sample preparation are also necessary.
- The analytical methods used in laboratory tests of flowback and produced water should have an appropriately defined limit of quantification and uncertainty, allowing for a correct comparison of the obtained test results, e. g. with the criteria set out in the legal regulations and the results obtained by different laboratories. A correctly defined limit of quantification is particularly important when determining the traces of the substances present in the liquid waste samples.
- Tests of shale gas operations wastes should be carried out by laboratories experienced in carrying out analyses of this type of waste and accredited in this field. These laboratories should also be a third party, i. e. they should not be associated with the shale gas operator.
- Both, returned fluids and solids (proppants, rock chips and tube scalings) need to be sampled and prepared for chemical analysis and monitoring as inorganic, organic and radioactive elements could be scavenged and sorbed on solid surfaces or newly precipitated.
- The complex composition of organic compounds needs an application of non-targeted analytical methods for screening and compound identification.
- Waste connected with shale gas operations should not enter the environment in an untreated form, even unintentionally, e. g. as a result of failure.
- Flowback water should be used on-site for further treatments. The transport of such waste to other locations for reuse or to mining waste disposal facilities should be in accordance with waste transport procedures. It is also possible to dispose flowback water via underground injection.
- Simulation of flowback water composition using numerical modeling is only possible with (1) extended geochemical data bases, especially for organic constituents and (2) improved process understanding of geochemical

mobilization from shales. With accordingly improved models other hypotheses need to be tested.

- On the short time frame it is recommended to deduce a purely data-driven model based on the existing experimental results. This would benefit input and output data of the system to find out specific patterns of the flowback and to be generalized for a broader range of data.

2.4 Recommendations on well site infrastructure and transport (*based on Report D12.5*)

When discussing the possible impact of shale gas exploration and exploitation on the environment, the impact of well site infrastructure and transport should also be taken into account. The guidelines for well site infrastructure and transport prepared as part of the M4ShaleGas project are presented below (*Worrall et al., Report D12.5, 2017*):

- Multi-well pads, i.e. pads with multiple wells, should be encouraged as they not only increase regulatory efficiency for operators but also reduces surface disturbance.
- Appropriate drilling rigs and the most up to date drilling technology should be used, so drilling is efficient and minimally obstructive as possible.
- Sensible setbacks (eg. 150 m or more) need to be established and enforced to protect public safety, in addition to ecological, historical, cultural, recreational and aesthetic resources.
- Developments in areas already disturbed should be encouraged, an optimal location for wells pads and associated facilities would be industrial parks designed for this type of industrial activity, and/or in close proximity to major roads designed to handle frequent heavy goods transportation.
- A comprehensive planning process to assess the cumulative impacts of multiple shale gas developments should occur pre-development.
- In general multi-well pads with long laterals reduce the cumulative surface footprint and generate more gas reserves, however, this is not always the case. License block need to be assessed on a site by site basis to determine the most appropriate lateral length.
- It must be considered that surface spills and leaks will occur but these will not be out of line with existing transport systems (eg. milk or oils) and the industry should design safety systems and training as used for oil tankers.
- The use of existing roads and right of ways should also be encouraged, as this can reduce additional surface footprint and cumulative impacts on the landscape.
- The traffic impacts are likely to be local rather than national, although care should be taken to consider cumulative effects that would occur as the number of well pads expands.

3 BEST PRACTICES AND RECOMMENDATIONS FOR MINIMISING THE ENVIRONMENTAL FOOTPRINT OF SURFACE SHALE GAS OPERATIONS – SUMMARY

Surface operations related to shale gas exploration and exploitation have a potential impact on environmental elements such as groundwater, surface water and soil. Generated waste and the entire infrastructure associated with shale gas operations also can have an influence on the environment and public safety. In such a situation, only the application of appropriate standards and procedures can contribute to guaranteeing safety for the environment and human health.

As part of the SP2 task, following a detailed analysis of the recommendations proposed by the individual research groups for this task, general recommendations for minimising the environmental footprint of surface shale gas operations in Europe have been developed:

- There is a need to monitor the state of the environment in exploration and production areas of unconventional hydrocarbon deposits. Monitoring should be carried out before beginning of work (baseline monitoring), during drilling and operation, as well as until a certain time after completion of the work.. The scope of monitoring should include noise levels, air emissions, control of soil and water quality (surface and groundwater) as well as measurements of methane content in soil gas. The scope of monitoring and its frequency should be determined individually according to the stage of works, geological and hydrogeological conditions, drilling technology or the means and materials used for drilling.
- The environmental monitoring system dedicated to shale gas operations should provide information on possible pollution (soil and water) as quickly as possible, determine the scale and extent of any pollution, identify the source of contamination and take appropriate corrective action.
- All environmental monitoring data, including baseline monitoring, and details of the technology and type and quantity of chemical substances used in shale gas operations, as well as data on the composition (quantitative and qualitative) of the waste generated, should be collected and stored in a publicly accessible database managed by an authorised unit. Storage of this information will make it possible to determine the environmental impact of potential shale gas operations spills and accidents.
- Environmental monitoring, as well as waste research, should be carried out by an independent unit experienced in such research, commissioned by a company engaged in exploration and production of unconventional hydrocarbon deposits. Such an unit should also be a third party, i. e. they should not be associated with the shale gas operator.
- During monitoring, as in waste research, appropriate testing methods should be used, with a defined limit of quantification and uncertainty. In addition, where liquid waste analysis is carried out, a procedure for the collection and

preparation for testing of such samples should be developed which is appropriate for the purpose of testing.

- A water resource management plan should be drawn up for each well pad prior to the start of the works, taking into account the availability of fresh water, its quantity and composition, as well as the composition of liquid waste (to determine reusability).
- Efforts should be made to reduce the use of chemicals or to use non-hazardous substances wherever possible.
- There is a need to store chemicals, fracture fluids and liquid waste in closed tanks, away from surface water, aquifers and other sensitive areas, identifying buffer zones after individual testing. It is also possible to dispose flowback water via underground injection. This approach should reduce the possibility of leakages or uncontrolled air emissions. Disposal or storage of hydraulic fracturing liquid waste in unlined pits, resulting in contamination of groundwater must not take place.
- There is a need to amend the existing waste classification and management legislation with requirements for the classification and handling of shale gas operations liquid waste (flowback and produced water).
- There is a need for full disclosure of environmental monitoring data and data on the composition (quantitative and qualitative) of the technological fluids used during shale gas operations and information on the composition and properties of the waste generated, as well as information on how to further manage the waste.
- The basic scope of physicochemical tests of flowback and produced water for potential environmental impact should include at least the determination of general parameters, metals (including heavy metals), anions and aliphatic and aromatic hydrocarbons. Knowledge of the flowback and produced water composition will enable selection of the appropriate waste treatment method and/or informative decision on further disposal or storage of the waste.
- Waste connected with shale gas operations should not enter the environment in an untreated form, even unintentionally, e. g. as a result of failure.
- Flowback water should be used on-site for further treatments. This flowback water management method reduces water consumption and contributes to the correct management of water resources.
- The transport of waste from shale gas operations to other locations for reuse or to mining waste disposal facilities should be in accordance with waste transport procedures.
- It is recommended to use existing roads during shale gas operations, especially as the traffic associated with exploration and production of unconventional hydrocarbon fields is rather local.
- Exploration and exploitation should, as far as possible, be carried out in degraded areas, an optimal location for wells pads and associated facilities would be industrial parks designed for this type of industrial activity, and/or in

close proximity to major roads designed to handle frequent heavy goods transportation.

- It is recommended to use the most modern drilling technology, effectively insulate aquifers, create multi-well pads and apply appropriate protection of the shale gas operations site.

Taking into account the guidelines on minimising the environmental footprint of surface shale gas operations in Europe developed as part of the M4ShaleGas project should contribute to minimising the environmental impact of surface shale gas operations. The application of the recommendations should also help reduce concerns among local communities.

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