HYDRAULIC FRACKING SUSTAINABILITY ASSESSMENT:

CASE OF STUDY LUENA (CANTABRIA, SPAIN)

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ABSTRACT

The opposition to Hydraulic fracturing in Cantabria, has led the Regional Government to enact a law that prohibits their use in the region, which has been suspended by the Central Government.

The objective of this work is to Identify impacts on the environment, and the main economic and social factors (sustainability) in a case of study Luena research permit (with an estimated shale gas reserves of $10.34*10^9$ Nm^3), establishing a guide for assessing the activity of hydraulic fracturing under the rules of strategic environmental assessment of plans and programs

The results indicate that the greatest impacts of developing the technique in the Luena permit, are on land take and the groundwater pollution, which could affect the water supply of the urban area of Santander (Very High). Judged as High Risk are air releases, with HAPs and total methane emissions, surface water pollution, biodiversity and traffic.

Profitability is strongly conditioned to lower implementation costs of the well, determined by the development of technology in Europe, not being profitable at current costs.

The employment is estimated in 5000 jobs in total, although mostly temporary, and outside the community.

There is a risk of human health effects at sites located within the 1/2 mile radio, with headaches and increased risk for cancer.

As a conclusion it is noticed that the large-scale development of fracking in a Region represents a substantial energetic change that should be contemplated in the Energy Plan of a Region and Country.

Environmental and health effects should be evaluated on the basis of Directive 2011/92/EU

on the assessment of the effects of certain public and private projects on the environment. Other aspects of sustainability (economic and social) must be taken into account to make a final decision.

KEYWORDS: Fracking, Hydraulic fracturing, Cantabria, Luena, Permit, Shale gas, Sustainability, Economic benefit, Environmental, Social, Health, Well, Energy.

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1. SCOPE

1.1. BACKGROUND

The biggest energy story that has happened in the 21st century so far is the extraction of natural gas from shale rock formations in the United States. The combination of horizontal drilling and hydraulic fracturing enables the extraction of huge quantities of natural gas from impermeable shale formations, which were previously thought to be either impractical or uneconomic. The extraction of shale gas has transformed the US energy landscape **[1]**.

Fracking is expected to contribute $321.1 billion to the U.S. gross domestic product by 2050. and experts have posited that, at current consumption levels, shale reserves could meet American energy needs for 100 years [2].

The technically recoverable shale gas volumes for Europe were estimated by the US Department of Energy to 18 Tcm. Poland, France, Norway and Ukraine host the larger estimates **[3]**, as can be seen in Figure 1.

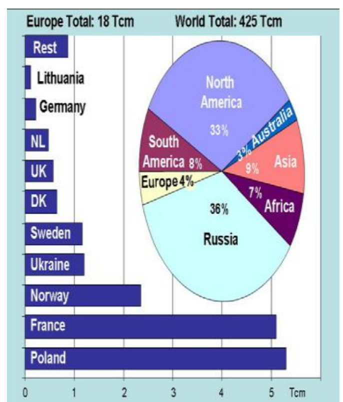


Figure 1. World shale gas Inventory of 2011. Source [3]

The outlook for the existence of shale gas in Spain are more modest than in the United States. The main prospective areas are located in the Basque-Cantabrian, Pyrenees, Ebro, and Guadalquivir basins Andalusia (Figure 2).

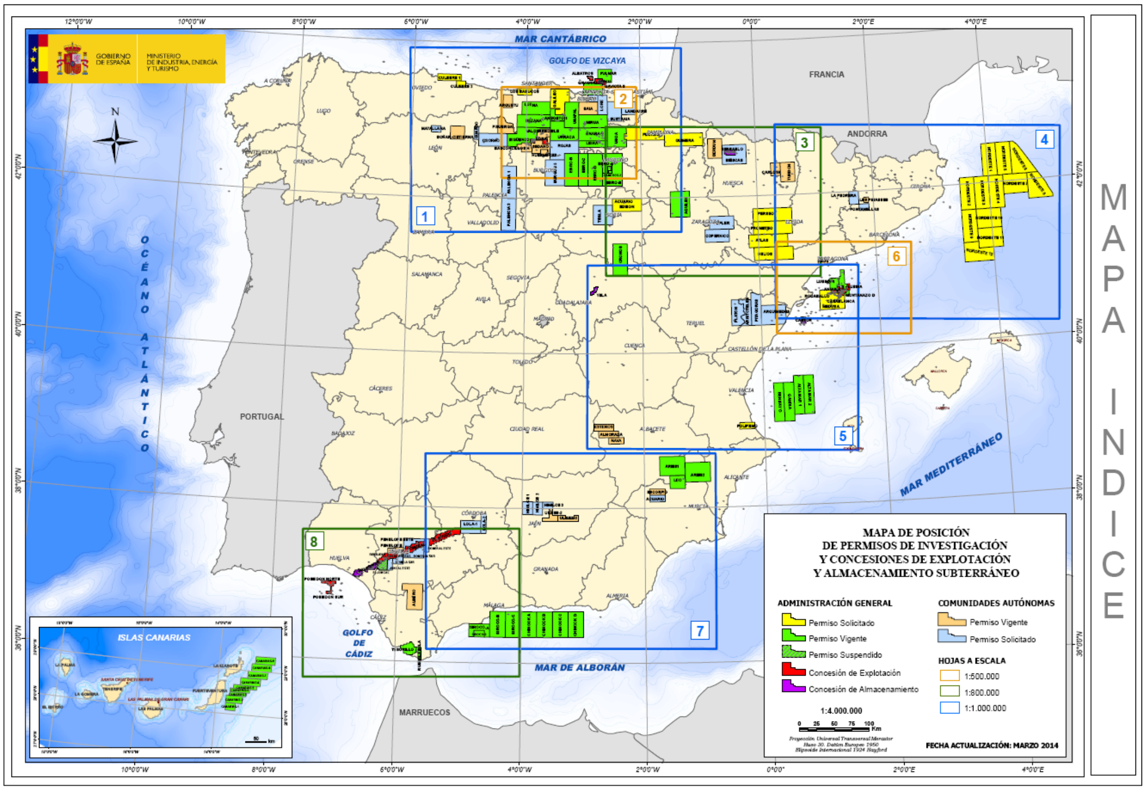


Figure 2. Position map of shale gas research permits. Source: website of the Ministry of Industry, Energy and Tourism

Currently in Spain there are numerous research permits requested and granted by the competent authorities (regional and state, depending on whether it covers one or more regions), as shown in Table 1.

Table 1. Research permits requested and granted, 2014.

Source: website of the Ministry of Industry, Energy and Tourism

	State Authority	Regional Authority
Permits requested	25	32
Permits granted	48	22

Supporters of hydraulic fracturing argue the economic benefits of the vast amounts of previously inaccessible hydrocarbons, that this new technique allows to extract, making Europe less dependent on external energy. Table 2 shows primary energy production and consumption in Europe, EE.UU. , Spain and Cantabria.

Table 2. Dependence on external primary energy in Europe, Spain and Cantabria. Developed from the Energy Information Administration (EIA), and Industry Department of Cantabria information (referred to 2011).

	Primary Energy Production (Gwh)	Primary Energy Consumption (Gwh)
EE.UU.	$30.97 \cdot 10^{6}$	$34.74 \cdot 10^{6}$
EU-27	$9.22 \cdot 10^{6}$	$2.13 \cdot 10^{7}$
Spain	$4.50 \cdot 10^{5}$	$1.79 \cdot 10^{6}$
Cantabria	9.5810^{2}	$4.66 \cdot 10^{4}$

Opponents, however, say the environmental impact of this technique, including groundwater contamination, high water consumption, air pollution, noise pollution, migration of gases, and chemicals used to surface contamination due to surface spill, and the potential health effects resulting from these hazards. Were also produced cases of increased seismic activity, most associated with deep injection of fracking-related fluids in the subsurface.

For these reasons, hydraulic fracturing has been the subject of international attention, being promoted in some countries, while others have imposed moratoriums on the use or banned (France). Some of these countries, such as UK, recently lifted its veto, opting for regulation rather than banning. The European Union is now starting to regulate hydraulic fracturing.

This opposition to fracking has been particularly intense in Cantabria with several research permits pending or granted, with the creation of citizens' groups and environmentalists opposed to fracking.

This situation has forced the Government of Cantabria to pass a law that prohibits the hydraulic fracturing technique in the region (Cantabria Act 1/2013, of 15 April, by which it regulates the prohibition of hydraulic fracturing technique on the territory of the Autonomous Community of Cantabria as a technique for research and unconventional gas extraction).

The Plenum of the Constitutional Court has admitted the appeal filed by the Government of Spain against Cantabria Act 1/2013, agreeing the automatic suspension of the Law until appeal resolution.

1.2. OBJECTIVES

In the context of conflict between the positions pro and against the exploitation of shale gas resources, particularly in Cantabria, information about positive effects on the economy and employment, and negative effects on environmental and health people, is large, but often offers a partial view of the problem, addressing some of the issues identified regardless the rest.

The widespread use of the hydraulic fracturing technique should consider the concept of sustainable development first formulated in the Brundtland report of 1987 (the result of the World Commission on Environment and Development United Nations). Sustainable development is based on three factors: society, economy and environment (see Figure 3)

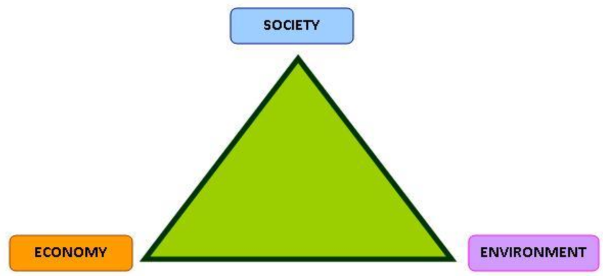


Figure 3. Triangle of sustainability.

Keep in mind that although it has been requested some permissions to perform exploratory wells, the development of shale gas is based on exploitation of resources scattered over a large area of rock. The number of wells drilled to full recovery must be high, and therefore, the development of shale gas should be subject to strategic environmental assessment of plans and programs in accordance with Article 6. a) of Act 21/2013, of 9 December, on environmental assessment. (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).

Moreover, **the possible development of shale gas resources exploitation in Cantabria or Spain should not be done without being previously referred in a national or regional Energy Plan**, so this Plan should be subject to the strategic environmental assessment procedure.

Given the above, the objectives of this work are:

1. **Identify potential impacts on environmental, economic and social factors (sustainability) on development of the technique of hydraulic fracturing in Cantabria, through Luena research permit, and quantifying them where possible.**

2. **Establish a guidance document for assessing the activity of hydraulic fracturing under the rules of strategic environmental assessment of plans and programs.**

1.3. DESCRIPTION OF HORIZONTAL HYDRAULIC FRACTURING TECHNIQUE

1.3.1. Unconventional Gas Resources

Depending on the geological formation, the oil and gas formed escaped from the bedrock and usually migrated upward into porous and permeable strata, which in turn had to be covered with impermeable rocks, called the seal to create hydrocarbons deposits. These accumulations of hydrocarbons form the conventional oil and gas. Its relatively high oil content, its position a few kilometers below the surface, and ground access facilitated easy removal by drilling wells.

Hydrocarbons can also be stored in large volumes in rocks, in principle, are not reservoirs but shale and other fine-grained rock in which the storage volume needed is constituted by small fractures and pore spaces extremely small (Table 3). These rocks have extremely low permeability. These hydrocarbons are called shale gas or oil shale. The latter does not contain mature hydrocarbons, but only its precursor called kerogen, which can be transformed into synthetic crude oil in chemical plants.

Depending on the characteristics of the reservoir, the gas contains different constituents in different proportions, such as methane, carbon dioxide, hydrogen sulphide, radioactive radon, etc.

<u>All unconventional deposits have in common that the gas or oil content by volume of rock is reduced compared to conventional reservoirs, which are scattered over a large area of tens of thousands of square kilometers and its permeability is very low. Therefore special methods to extract the oil or gas that is required.</u>

Table 3. Generating potential based on TOC content and the type of bedrock. Source [4].

Potencial Generador de Hidrocarburos en función del Carbono Organico Total (TOC) Basado en una ventana de petróleo en maduración temprana		
Potencial Generador de Hidrocarburos	TOC en Pizarras, % en peso	TOC en Carbonatos, % en peso
Pobre	0,0 a 0,5	0,0 a 0,2
Aceptable	0,5 a 1,0	0,2 a 0,5
Bueno	1,0 a 2,0	0,5 a 1,0
Muy bueno	2,0 a 5,0	1,0 a 2,0
Excelente	> 5,0	> 2,0

The gas can be found in shale or slates, fractures and joints in free form and in the form adsorbed on the carbonaceous microparticles.

1.3.2. Horizontal Hydraulic Fracturing

The technique of hydraulic fracturing, or fracking, has been used since 1949 to improve oil recovery in older wells, conventional reservoirs. The development of new technologies has led to their use for the exploitation of unconventional gas such as shale gas resources.

The permeability determines the degree of connectivity of the pores and fractures that exist in any sedimentary rock. If the pores and fractures are poorly connected, any fluid will be difficult to move and be applied artificial methods to induce permeability in the rock in order to reach commercial production (Figure 4).

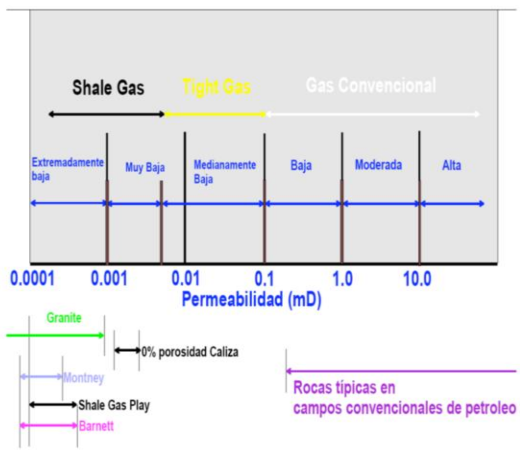


Figure 4. Permeability ranges for conventional and unconventional gas reservoirs. Source [4].

The fracking technique currently used is a combination of vertical drilling (usually up to 2,500 m deep), and horizontal drilling with subsequent creation of fractures in rock formations containing gas in its pores (Figure 5). For this, a fluid is injected under high pressure (approx. 90% water, and chemicals) to create channels in the rock which the migration of gases into the well of extraction (Figure 6). Surface treating pressures sometimes are less than 100 psi, others may approach 20,000 psi **[5]**

In order to avoid the natural fracture closure, when the hydraulic pressure in the hold open is relaxed, is pumped, together with water, a support agent (proppant), typically sand, which keeps the fracture open in permanently.

The technique of hydraulic fracturing, combined with horizontal drilling (up to more than 2 km horizontal), developed in the 80s have allowed the exploitation of shale gas in the U.S., began in 2002, with tens of thousands of wells in operation today.

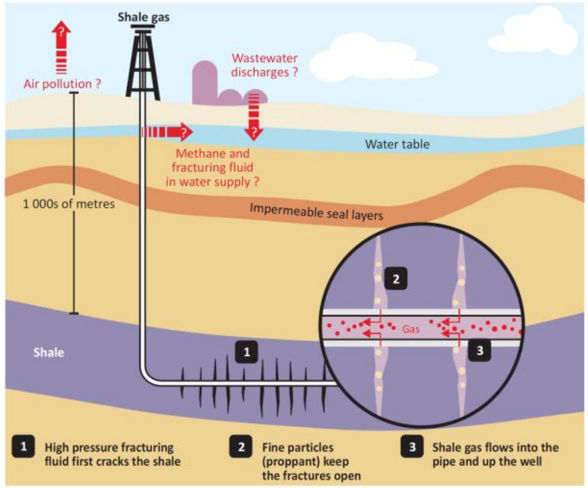
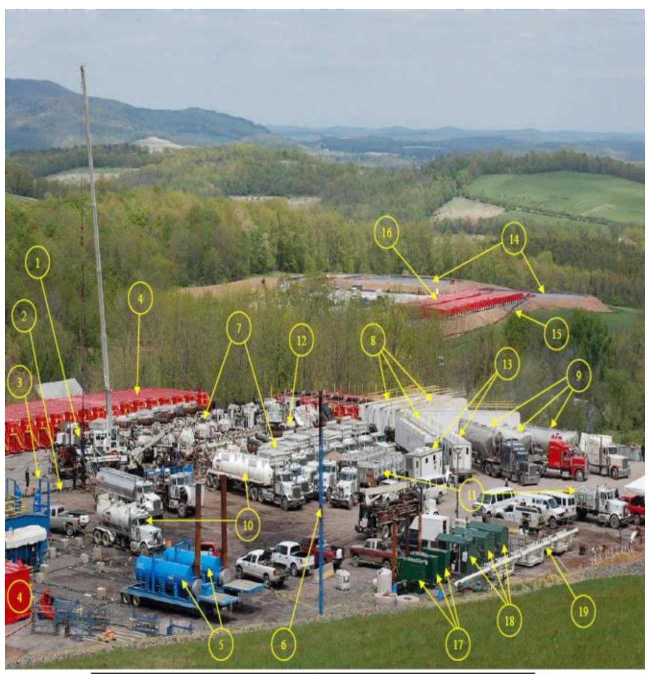


Figure 5. Hydraulic fracturing scheme. Source [6]

After the fracturing is completed, the internal pressure of the geological formation makes injection fluids go to surface (well completing) where they can be stored in tanks or lagoons before disposal (dumping into water courses or underground injection) or recycled (for reinjection) **[2]**.



1. Well head and frac tree with 'Goat Head'
2. Flow line (for flowback & testing)
3. Sand separator for flowback
4. Flowback tanks
5. Line heaters
6. Flare stack
7. Pump trucks
8. Sand hogs
9. Sand trucks
10. Acid trucks
11. Frac additive trucks
12. Blender
13. Frac control and monitoring center
14. Fresh water impoundment
15. Fresh water supply pipeline
16. Extra tanks
17. Line heaters
18. Separator-meter skid
19. Production manifold

Figure 6. A well site during a single hydraulic fracturing operation, New York State 2009. Source [7]

1.4. REGULATORY FRAMEWORK

In this section the most important regulatory issues related to hydraulic fracturing are indicated. Only state wide regulations are mentioned. In Annex 1 a complete collection including European Directives, regional and local rules are detailed.

At European level there is no Framework Directive that regulates specifically hydraulic fracturing or mining activities. At State level:

Sectorial regulatory framework.

- Act 34/1998 of 7 October, of the hydrocarbons sector.

  In Section II, exploration, research and exploitation of hydrocarbons is regulated. Resources have “demanial” character. Exploration permit, research permit, or exploitation concession are required.

  Regional governments are competent in granting license to prospect for hydrocarbons in its territory.

  State Government is the competent authority in granting exploration or research permits covering more than one region. It is also the competent authority to grant exploitation concessions regardless of territory.

- Hydrocarbon Law is amended to include hydraulic fracturing through the following law :

  Act 17/2013, of 29 October, for the security of supply and increased competition in non-mainland electricity systems.

  Second final provision. Amendment of Act 34/1998 of 7 October, of the hydrocarbons sector.

  A new paragraph 5 is added to Article 9 of Law 34/1998 of 7 October, of the hydrocarbons sector, with the following wording:

  "5. In the development of the work to be executed under the titles mentioned in this article geophysical and geochemical methods may be applied Prospecting, drilling vertical boreholes or deviated with eventual application of standard techniques in the industry, including hydraulic fracturing, the well stimulation and secondary recovery techniques and those other air, sea or ground methods which are necessary for its object.”

Environmental regulations.

- Act 21/2013 of 9 December of environmental assessment.

  This act integrates the Strategic Environmental Assessment Directive (2001/42/CE) and Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment.

  Including in Annex I :

  "Group 2. Extractive industry.

  d) Projects consisting of drillings for exploration, research and exploitation of hydrocarbons, CO_2 storage, geothermal and gas storage and medium and high enthalpy, requiring the use of hydraulic fracturing techniques.

  Not included in this section drilling of core samples prior to drilling projects requiring the use of hydraulic fracturing techniques.

  Facilities and structures necessary for the extraction, processing, storage, use and transport of ore, sterile stockpiles, ponds, and power lines, water supply and treatment, and new access roads, are included in all sections of this group."

  The Environmental Assessment corresponds to the State if the project covers more than one region.

- Cantabria Act 17/2006 of 11 December on Integrated Environmental Control.
- Cantabria Act 1/2013, of 15 April, that regulates the prohibition on the territory of the Autonomous Community of Cantabria the technique of hydraulic fracturing as a technique for research, and unconventional gas extraction.

More information in Annex 5. 1.

1.5. SHALE GAS IN CANTABRIA

1.5.1. Basque-Cantabrian Basin Resources

In Cantabria, the geological formation with shale gas belongs to the Lias (Jurassic). In Deep Luena-1 (first exploration well), is planned to drill 2500 m depth from the ground level down to achieve this formation **[8]**.

Available studies indicate that Lias shales of the Basque Cantabrian Basin have the characteristics to be exploited by the technique of fracking:

"Throughout the paper we have described an organic facies over 100 meters total thickness, with 25-30 net meters, of black shales in Jurassic subsiding domains such as Line Polientes-Tudanca, and organic carbon contents that far exceed the threshold of 2% by weight of TOC, generally assumed for commercial projects. Regarding the level of maturity, generally is assumed 80% transformation ratio, corresponding to levels of maturity of the late oil window and transition to gas window, as the threshold for the development of more profitable projects. This threshold has clearly been exceeded in large areas of the Basque-Cantabrian subsiding basin where the location of the most promising areas is estimated. Preliminary volumetric calculations using the methodology proposed by Jarvier et al. (2007) fit within the range of values for successful projects in the U.S. "[9].

According to the U.S. Energy Information Administration the Basque-Cantabrian Jurassic Formation (Lias) contains an estimated 42 Tcf (tera cubic feet) resources, with reserves (technically recoverable) of 8 Tcf.(Table 4) [10]

Table 4. Shale gas reservoir properties and resources of Spain. Source [10]

Basic Data	Basin/Gross Area		Basque-Cantabrian ($6{,}620\ mi^2$)
	Shale Formation		Jurassic
	Geologic Age		L. - M. Jurassic
	Depositional Environment		Marine
Physical Extent	Prospective Area (mi^2)		2,100
	Thickness (ft)	Organically Rich	600
		Net	150
	Depth (ft)	Interval	8,000 - 14,500
		Average	11,000
Reservoir Properties	Reservoir Pressure		Slightly Overpress.
	Average TOC (wt. %)		3.0%
	Thermal Maturity (% Ro)		1.15%
	Clay Content		Medium
Resource	Gas Phase		Wet Gas
	GIP Concentration (Bcf/mi^2)		49.8
	Risked GIP (Tcf)		41.8
	Risked Recoverable (Tcf)		8.4

Based on these data, the Luena permit subject of this study, **in proportion to its surface area ($746.28\ km^2$, 4.35%)**, **would contain a risk recoverable resources of $10.34 \cdot 10^9\ m^3$, with an estimated value of 3,654 MM $ (10 $/MMBtu)**.

1.5.2. Research Permits in Cantabria

At present there are eight permits granted affecting territory of Cantabria (website of the Ministry of Industry, Energy and Tourism; Figures 7,8):

- Arquetu
- Galileo
- Usapal
- Angosto 1
- The Basucos
- Bezana
- Bigüenzo
- Luena

Of all the above permits, affecting part of the territory of the CA of Cantabria, only Arquetu and The Basucos permits do not affect neighboring Communities. The Arquetu permission is therefore responsibility of the CA of Cantabria. However The Basucos permit is responsibility of the State because it affects the marine environment.

This study focuses on the Luena permit whose main features are:

- LUENA:

Royal Decree 1772/2010 of 23 December, by which the hydrocarbons research permit called "Luena" is granted to Repsol Investigaciones Petrolíferas, S.A., for a period of 6 years. State Official Gazette, January 22, 2011. Area: 74,628 hectares.

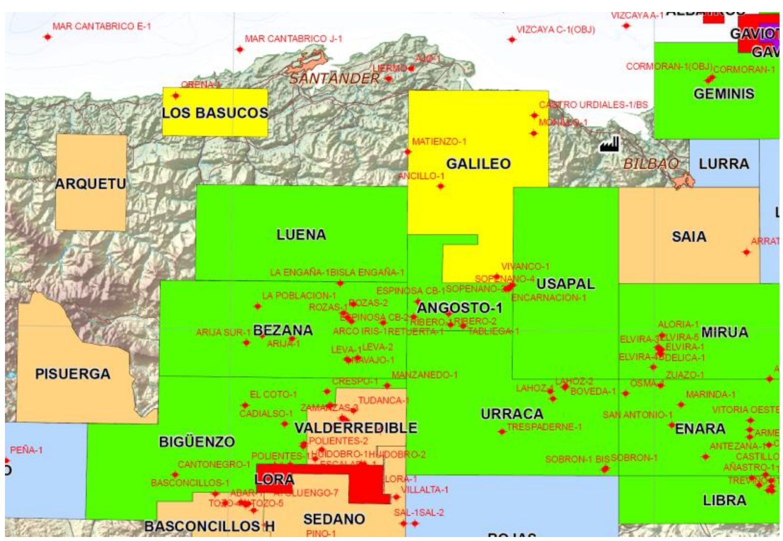


Figure 7. Research permits in Cantabria (2014, March). Source: website of the Ministry of Industry, Energy and Tourism

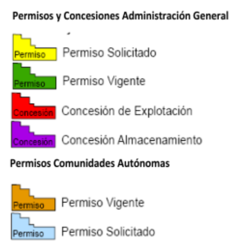


Figure 8. Leyend. Source: website of the Ministry of Industry, Energy and Tourism

1.6. CASE STUDY: LUENA PERMIT

1.6.1. Permit Definition

To assess the sustainability of the technique of hydraulic fracturing in Cantabria, it was considered the study of Luena permit, whose processing is well advanced, having been authorized works of exploratory and drilling a borehole named Luena-1.

The Luena permit covering the Autonomous C. of Cantabria and Castilla y León, and is defined by the following coordinates(Table 5) :

(Real Decreto 1772/2010, de 23 de diciembre)

Table 5. Permit Luena UTM coordinates. WGS84 ellipsoid. Zone 30.

Transformed from geographic coordinates, R.D. 1,772/2010.

Vértice	X	Y
1	412.058	4.789.147
2	452.647	4.788.743
3	452.518	4.770.234
4	411.818	4.770.638

Permit lies in the county of Vega de Pas, affecting mainly (for the most affected area) to the following municipalities (Figure 9):

- Corvera de Toranzo

- Villacarriedo
- San Roque de Riomiera
- Selaya
- Vega de Pas
- San Pedro del Romeral
- Luena
- Molledo
- Anievas
- Arredondo
- Soba
- Santiurde de Toranzo

(13,591 population. Source: Icane. Census 2013)

Other municipalities affected are the following: Cieza, Corrales de Buelna, San Felices de Buelna, Villafufre, Saro, San Miguel de Aguayo, Pesquera, Bárcena de Pié de Concha and Arenas de Iguña.

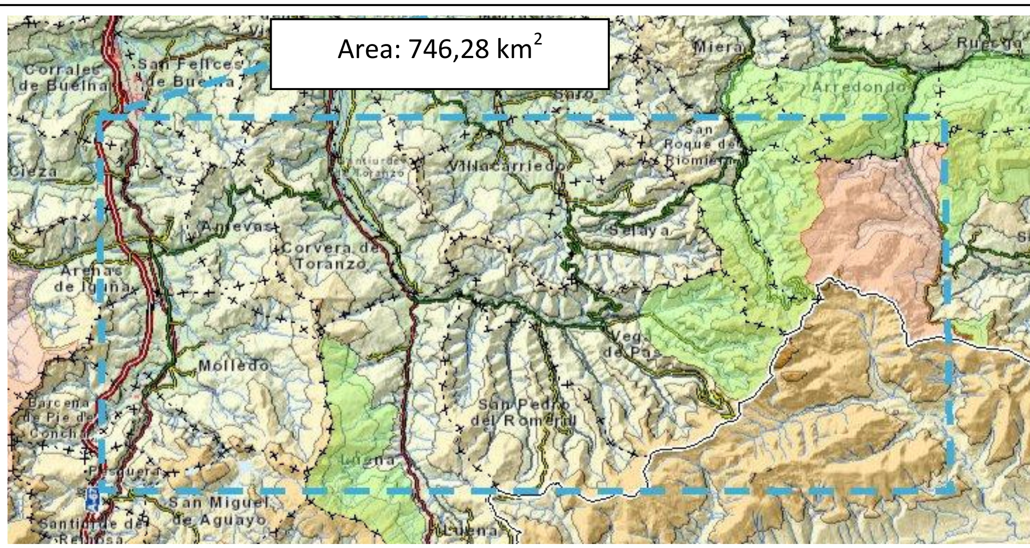


Figure 9. Luena permit extension. In pink Parque Natural del Ason. In green the LIC Montaña Oriental and LIC

The Luena permit includes the following works (Royal Decree 1772/2010 of 23 December):

First three years:

a) Geology and geophysic works:

- Seismic interpretation, seismic processing and 2D seismic registration (if necessary).
- Geochemical sampling and laboratory analysis.
- Review and study of drillings in the area. Petrophysical studies.
- Mining area analysis and geochemical modeling.

b) Drilling a borehole. Depending on the results obtained at the end of third year, decide whether to renounce the permit or continue to the next exploration program.

Fourth to sixth year:

a) Geological detailed studies with the information obtained from the borehole drilling of the previous step.

b) Works of geology and geophysics, advanced integration and improvement of exploratory data worked in the first three years.

c) Risk assessment, reserves and commerciality integrating all existing technical and economic information.

d) Based on the results of previous studies, will be made a second exploration well.

The minimum investment by the company during the first three years amount to 15,000,100.00 euros, and the fourth to the sixth year of operation, a minimum investment of EUR 15,000,000.00.

1.6.2. Exploration Well

The exploration well, called Deep Luena-1 has the following features **[8]**:

Depth 2,500 m. Different locations are being considered, to determine in accordance with the results of previous seismic survey, all between San Pedro de Romeral and Vega de Pas municipalities (Figure 10).

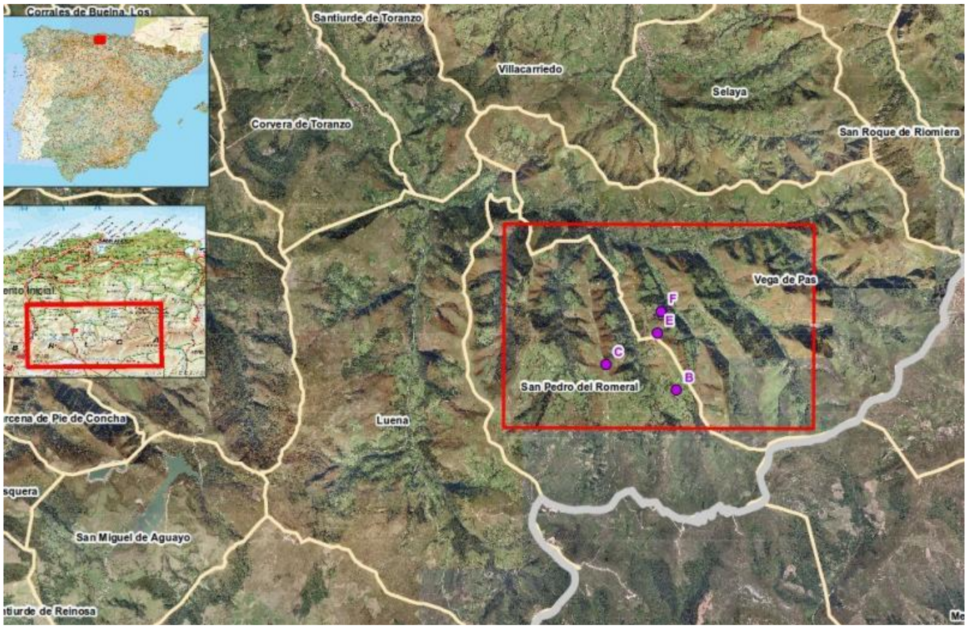


Figure 10. Possible locations of Deep Luena-1 exploration well. Source [8]

Access and work platform

The width of the Access to Deep Luen-1 well will be 8 m. The site will have approximate dimensions of 150m * 150m (Figure 11).

The site consists of 4 ponds of 1,800 m^3 each (20 * 30 * 3m) with polyethylene waterproofing .

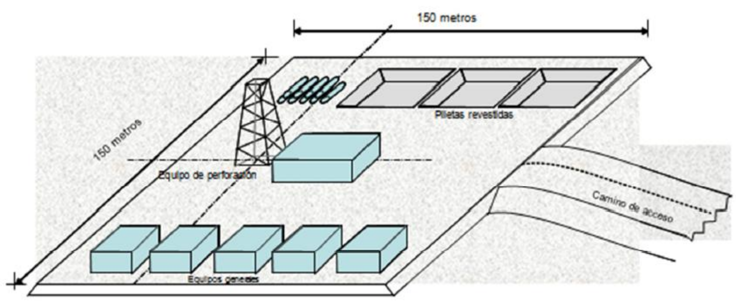


Figure 11. Well platform drawing. Source [8]

Water consumption

Consumption of 2000 m^3 of water for the drilling, is estimated. In the process of stimulation, it considered four sections to fracture (at different depths between 2.017my 2.385m) with a total consumption of 6,400 m^3.

The water supply shall be made by tankers. The flow-back water treatment (10-30%) will be made by authorized waste treatment manager or by wastewater treatment station.

1.7. METHODOLOGY FOR ASSESSING THE SUSTAINABILITY

For the evaluation of the shale gas exploitation sustainability in Luena permit, it´s going to be used a semiquantitative methodology of impacts assessment, on the three factors of sustainability: environmental, economic and social.

Numerous sources were consulted in order to obtain accurate information on the experience gained in the EE.UU. mainly. The methodology applied to each factor is described below.

1.7.1. Methodology for Environmental Factors.

The main impacts are evaluated considering the different stages of development of a well and the cumulative effect of multiple installations in the Luena permit (estimated in 352 wells).

The stages are:

1. Well pad site identification and preparation.
2. Well design, drilling, casing and cementing.
3. Technical hydraulic fracturing stage.
4. Well completion.
5. Well production.
6. Well abandonment.

To assess potential impacts on the environment, potential risks are classified as a combination of hazard and the occurrence probability, according to the matrix below (Table 6).

Table 6. Risk table. Adapted from King PR 2012, after Demong et. al., 2010. Source: [11]

Probability classification	Hazard classification					
	Slight	Minor	Moderate	Major	Catastrophic	No data
Rare	Low	Low	Moderate	Moderate	High	Not classifiable
Occasional	Low	Moderate	Moderate	High	Very high	
Periodic/short term definite	Low	Moderate	High	Very high	Very high	
Frequent/long-term definite	Moderate	High	Very high	Very high	Very high	
No data	Not classifiable					

The risk prioritisation was carried out by classifying environmental hazards and human hazards on the following basis [11]:

• **Slight:** Slight environmental effect– e.g. a planned or unplanned discharge which does not result in exceedances of an environmental quality standard.
• **Minor:** Minor environmental effect – e.g. a planned or unplanned discharge which could result in exceedances of an environmental quality guideline in the immediate vicinity of the release point, but which would not be expected to have significant environmental or health effects.
• **Moderate:** Localized environmental effect – e.g. a discharge or incident resulting in potential effects on natural ecosystems in the vicinity of the release point or incident; ongoing effects on people in the vicinity of a site due to impacts such as noise, odour or traffic.
• **Major:** Major environmental effect – e.g. an ongoing discharge resulting in persistent exceedances of European environmental quality standard; permanent degradation of a protected habitat.
• **Catastrophic:** Massive environmental effect – e.g. a pollution incident resulting in harm to the health of members of the public over a wide area due to contamination of drinking water supplies; accident resulting in death or serious injury to workers and/or members of the public.

The frequencies or probabilities of hazards occurring were classified on the following basis [11]:

• **Rare:** Encountered rarely or never in the history of the industry; not forecast to be encountered under foreseeable future circumstances in view of current knowledge and existing controls on oil and gas extraction.
• **Occasional:** Encountered several times in this industry; could potentially occur under foreseeable future circumstances if management or regulatory controls fall below best practice standards.
• **Periodic:** Occurs several times a year in this industry; a short-term impact would be expected to occur with the use of hydraulic fracturing for hydrocarbon operations.
• **Frequent/definite:** Occurs several times a year at a specific site; a long-term impact would be expected to occur with the use of hydraulic fracturing for hydrocarbon operations.
Environmental factors considered:

1. Land take.
2. Air emissions.
3. Noise.

4. Groundwater contamination.
5. Surface water contamination.
6. Water resources.
7. Biodiversity impacts.
8. Traffic.
9. Visual impact.
10. Seismicity.

1.7.2. Methodology for Economic Factors

Capital costs and operating costs per well are analyzed, based on the bibliography.

Revenues are calculated based on the average production declining curve and Price forecast for natural gas by Worldbank.

Profitability parameters analyzed are: Net Present Value (NPV$), Internal Return Ratio (IRR%) and Payback (years). It has been developed a specific excel spreadsheet to evaluate the profitability of a shale gas well, applied to the Spanish mining and tax regulations.

Sensitivity analysis is performed, considering the variation of the gas price, capital and operation expenditures.

Based on literature, the possible loss of value of the properties affected by the permit Luena is quantified.

1.7.3. Methodology for Social Factors

The following issues were discussed:

1. Employment creation. It's quantified for full development of Luena permit, based on bibliography.
2. Possible health affection. The risk is classified based on bibliography.

2. DEVELOPMENT: CASE OF STUDY

2.1. ENVIRONMENTAL FACTORS

2.1.1. Land take

The land use requirement is greatest during the hydraulic fracturing stage, and lower during the production stage [11].

Land requirements include the locations of the well (well pad), access, pipes and other supply lines.

The places where the wells are located require the installation of ponds, tanks, fracturing equipment, emission reduction equipments, dehydrators, separators, and brine tanks.

The full exploitation of the resource may require make up to four phases of stimulation (re-fracturing) in 40 years [11].

The practice of developing multiple wells (Figure 12) from a single location ("paddrilling") reduces the use of surface (the need for new access roads, and additional traffic is lower). The operator identifies sites to be used as well pads. An individual well pad may typically have 6 to 10 well heads [11], each of which extends in a different direction from the site.

Translated into Figures, with a site of 2.5 hectares or less, you can cover an area of 5 km^2 exploitation, or more [4].

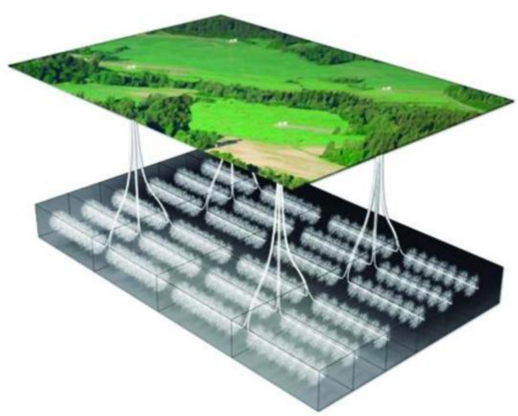


Figure 12. Multi-well pad. Source [7]

To estimate the land take in the Luena permit, it was determined the surface area available for possible locations of wells in the affected municipalities, after discounting the areas occupied by protected areas or urban spaces, and considering land as suitable for a well location less than 30% slope (Table 7).

Table 7. Surface area available for possible well locations.

Elaborated from ICANE data(Statistical Institute of Cantabria). 2014

MUNICIPALITY	AREA
39003 - Anievas	16,70
39007 - Arredondo	5,77
39026 - Corvera de Toranzo	36,34
39039 - Luena	28,94
39046 - Molledo	38,18
39071 - San Pedro del Romeral	33,53
39072 - San Roque de Riomiera	15,69
39078 - Santiurde de Toranzo	25,73
39082 - Selaya	16,33
39083 - Soba	45,11
39097 - Vega de Pas	13,83
39098 - Villacarriedo	30,65
Total (km^2)	**306,80**

According to the surface area available, and assuming an average density of 1.15 wells per km^2 [12], a number of 352 wells is obtained.

The area affected by Luena permit in case of individual wells, considering an average of 15,000 m^2 per well (the Deep Luena-1 well occupies 22,500 m^2) would be approximately 5.3 km^2, excluding accesses. This represents a 2.4% of industrial use of land. This compares to 4% of land in Europe currently occupied by uses such as housing, industry and transportation. [11]

Figure 13. Well pads image in Forth Worth (Dallas). Source: Googlemaps 2014

The evidence suggests that it may not be possible fully to restore sites in sensitive areas following well completion or abandonment, particularly in areas of high agricultural, natural or cultural value. Over a wider area, with multiple installations, this could result in a significant loss or fragmentation of amenities or recreational facilities, valuable farmland or natural habitats **[11]**.

This is the case of this typical rural environment, traditionally dedicated to pasture for livestock and forest exploitation.

The area affected by Luena Permit has a high agricultural, natural and symbolic value to Cantabrian Society: Los Valles Pasiegos.

The European Commission study -DG Environment (AEA)- **[11]**, identifies the accumulative effect overall rating across all phases as high.

Across all phases, it is judged to be of potentially major significance, and would be a short-term impact likely to be associated with the full development of any large shale gas concession and therefore classified as “short term definite” likelihood (Table 8).

Table 8. Risk on land take in Luena permit, across all phases

HAZARD	PROBABILITY	RISK
5.3 km^2 excluding accesses	Limited to the concession and the recovery of total reserves	**VERY HIGH**
2.4% industrial use, in a rural area		
Agricultural, natural value		
Symbolic value: Los Valles Pasiegos		
MAYOR	**SHORT TERM DEFINITE**	

The risk of a wide development of shale gas exploitation over this area is considered to be **VERY HIGH.**

2.1.2. Air Emissions

Emissions from numerous well developments in a local area or wider region could have a potentially significant effect on air quality. Emissions from wide scale development of a shale gas reservoir could have a significant effect on ozone levels. Exposure to ozone could have an adverse effect on respiratory health and this is considered to be a risk of potentially high significance **[11]**

The fracturing and completion stages also raises concerns about potential air quality effects. These typically include diesel fumes from fracturing liquid pumps and emissions of hazardous pollutants, ozone precursors and odours due to gas leakage during completion (e.g. from pumps, valves, pressure relief valves, flanges, agitators, and compressors).

There is also concern about the risk posed by emissions of hazardous pollutants from gases and hydraulic fracturing fluids dissolved in waste water during well completion or recompletion.

Fugitive emissions of methane (which is linked to the formation of photochemical ozone as well as climate impacts) and potentially hazardous trace gases may take place during routeing gas via small diameter pipelines to the main pipeline or gas treatment plant.

On-going fugitive losses of methane and other trace hydrocarbons are also likely to occur during the production phase.

Well or site abandonment may also have some impacts on air quality if the well is inadequately sealed, but they may be considered low.

In this work the study focuses on mayor impact pollutants : methane and other organic compounds (VOCs and PAHs).

2.1.2.1. Methane emissions

Methane emissions occur in the stages of preparation, drilling and fracturing, transport of water and chemicals, well completion, production and transportation of the product (Figure 14).

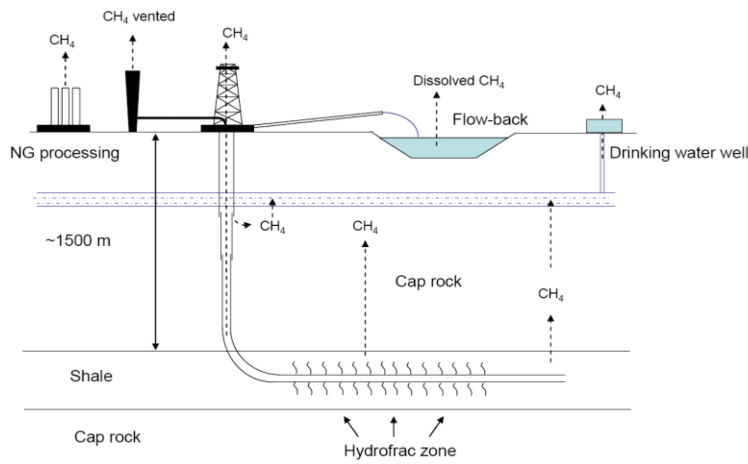


Figure 14. Potential flows of air pollutant emissions, harmful substances into water and soil, and naturally occurring radioactive materials (NORM). Source [12]

This study only considers direct emissions per well and no emissions throughout the life cycle, which include emissions from the production of materials and chemicals, nor are considered emissions of wastewater treatment, considering that the treatment is conducted to management facilities external to the well site.

In the completion stage, a combination of fracturing fluids and water with hydrocarbons is returned to surface. There are emissions in water separators, storage tanks, venting or combustion in flares. Commonly are demanding reduction systems of these emissions (Figure 15).

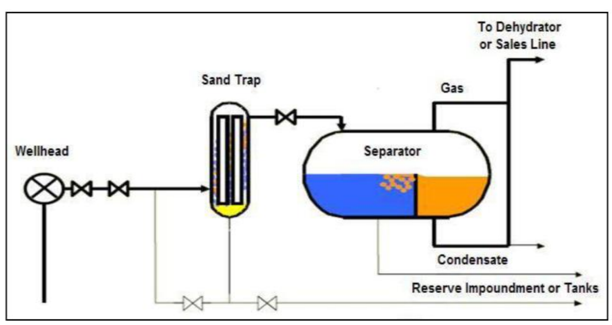


Figure 15. Reduced Emissions Completion Equipment (U.S. EPA 2011d). Source: [13]

Whereas an average annual production of 0.5 bcf per well, the first year (see section economic), annual production is equal to 16,000 t of raw gas (density= 0.07056 lb/cf [14]). Emissions would be 384 t CH_4 (80% methane; methane emissions 3%, see Table 9), equivalent to 11,520 t CO_2e per well (GWP = 30, 100 years, WG1-AR5 IPCC).

It makes more sense to calculate total emissions over the life of a well (because of the declining production curve). For this, it is considered a final recovery of 3.276 bcf per well, equal to 83.866 t CH_4, equivalent to 75,479 tCO_2e per well.

Complete development of shale gas in the Luena permit implies total emissions of 26.57 MM t CO_2e, quadruple the annual GHG emissions in Cantabria (6.69 MMt, inventory 2011).

Table 9. Estimates of methane emissions from upstream (at the well site) plus mid stream (at gas processing plants) of shale gas. Source [1]

Researchers	Shale gas (the percentage of methane produced over the lifecycle of a well)
Howarth et al [163]	3.3% (mean, range=2.2–2.4%)
EPA [72]	3.0%
Jiang et al. [43]	2.0%
Hultman et al. (2011)	2.8%
Stephenson et al. [86]	0.6%
Burnham et al. [60]	1.3%
Cathles et al. [154]	0.9%
Pétron et al. [57]	4.0% (mean, range=2.3–7.7%)

2.1.2.2. Emissions of other compounds

Shale gas production activities can produce significant amounts of air pollution that could impact local air quality in areas of concentrated development. In addition to GHGs, fugitive emissions of natural gas can release fugitive volatile organic compounds (VOCs), and hazardous air pollutants (HAPs), such as n-hexane, benzene, trimethylpentane, ethylbenzene, xylene and toluene.

Table 10. Fugitive HAPs emission factors for the Barnett Shale. Source [14]

Condensate tanks	3.7 lbs/bbl
Production	3.7 lbs/MMcf
Processing	1.8 lbs/MMcf
Transmission	0.3 lbs/MMcf
TOTAL	5.8 lbs/MMcf

Assuming the first year annual production, 1,315.4 kg of HAPs are released to the atmosphere for a single well (Table 10; were not taken into consideration emissions condensates).

For the full well life cycle, 8.6 t of HAPs are released. 3,027 t are released for 352 wells.

For methane, the hazard is classified as minor because of the probability of overcome reduction objectives established for non ETS GHG emissions (10% to 2020). The probability is long term definite (Table 11).

For HAPs, because of the hazardous compounds involved, the hazard is moderate, and the probability short term definite (Table 11).

Table 11. Risk on air emissions in Luena permit, across all phases

<table>
<tr><th>HAZARD</th><th>PROBABILITY</th><th>RISK</th></tr>
<tr><td>CH_4</td><td rowspan="3">Durable effects on Global Warming</td><td rowspan="8">HIGH</td></tr>
<tr><td>75,479 t CH_4 per well (over life cycle)</td></tr>
<tr><td>For all the permit, 26.57 MMt CO_2e, quadruple the annual GHG emissions in Cantabria</td></tr>
<tr><td>MINOR</td><td>LONG TERM DEFINITE</td></tr>
<tr><td>HAPs</td><td rowspan="3">Limited to the concession and the recovery of total reserves</td></tr>
<tr><td>1,315.4 kg HAPs per well (year), 8.6 t total</td></tr>
<tr><td>3 ,027t HAPs (total) in permit Luena</td></tr>
<tr><td>MODERATE</td><td>SHORT TERM DEFINITE</td></tr>
</table>

The risk of a wide development of shale gas exploitation over this area is considered to be **HIGH.**

2.1.3. Noise

Of all of activities, drilling of wells is likely to provide the greatest single continuous noise (and, light) pollution as drilling is required 24 hours a day. New York State estimates that each horizontal well takes four to five weeks of 24hours/day drilling to complete (Table 12). With development of multiple pads in a locality, noise impact is likely to be locally considerable and prolonged **[11]**.

Vehicle transport could affect residential amenity and wildlife.

Table 12. Assumed Construction and Development Times. Source: [15]

Operation	Estimated Duration (days)
Access roads	3 - 7
Site preparation/well pad	7 - 14
Well drilling	28 - 35
Hydraulic fracturing single well	2 - 5

Table 13. Noise levels. Data source: [15]

Operation	Noise levels to 609m (2,000 pies) dBA
Access construction	57
Site preparation	52
Perforation	44
Fracturing	72

Noise levels at night in a rural area like under study, can be below 30 dBA. Drilling and fracturing, with no mitigation measures may increase noise levels to 609 m from 37 to 42 dB (Table 13) [15].

According to the aforementioned information, acoustic quality objectives, regulated by the state (55 night-65 dBA, R.D. 1038/2012), would be exceeded at housing areas located less than 609 meters away.

Table 14. Risk on noise in Luena permit, across all phases

HAZARD	PROBABILITY	RISK
Areas located nearer than 1000 m	Drilling and fracturing phases, mainly	**HIGH**
Up to 72 dBA (609 m) at fracturing phase		
Probably acoustic quality objetives		
MODERATE	**SHORT TERM DEFINITE**	
Areas located further than 1000 m	Drilling and fracturing phases, mainly	**MODERATE**
Probably objetives exceeded at night		
MINOR	**SHORT TERM DEFINITE**	

The risk of a wide development of shale gas exploitation over this area is considered to be MODERATE-HIGH (Table 14).

2.1.4. Groundwater Contamination

The stages of greatest risk on groundwater contamination are fracturing, well completion and production [11]. The most likely mechanism of groundwater contamination is the leakage through inadequate cementation coating, or from intermediate formations through well annulus. Also surface contamination from spills. Is not sufficiently studied the pollution from the fractured formation (Figure 16).

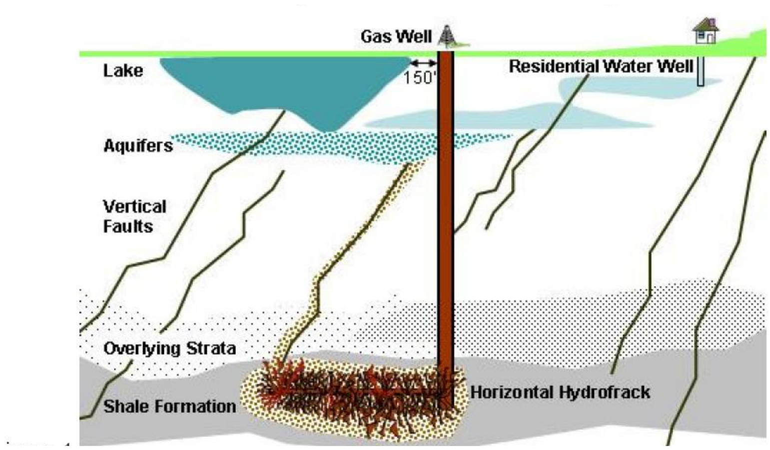


Figure 16. Groundwater contamination routes. Source: [16]

The fragility of shallow aquifer systems to possible contamination of fugitive gas, fracking fluids, and/or formation water depends primarily on the hydraulic connectivity between deep shale gas formations and the overlying shallow aquifers [17]. due to the presence of a strong network of fractures.

Contaminants may originate in the shale formations, dissolving into the fracturing fluid: CH_4, CO_2, H_2S, N_2, He, trace elements such as Hg, As, Pb, Ra, Th, U, and VOCs such as benzene.

Other contaminants may originate in the drilling/stimulating fluid containing hazardous substances as hydrochloric acid, polyacrylamide, dimethylformamide, ethylenglicol, isopropanol etc. [8].

The risks of hydraulic connectivity between the two, need to be fully evaluated before fracking operations begin. This issue of geometry, and the precision with which the geometry of subsurface rock formations can be quantified, is particularly important in regions where the tectonic structure (and history) are more complex e.g. NW Europe. Many US shale gas formations are relatively simple and flat lying, with aquifers positioned several kilometers above: this is not the case in many other basins around the world [18].

From a hydrogeological point of view, the study area is located on 012 017 groundwater bodies, called Puerto del Escudo and 012 010, called Alisa-Ramales as shown in Figure 17. These groundwater bodies belong to the Cantabrian Hydrographic Confederation.

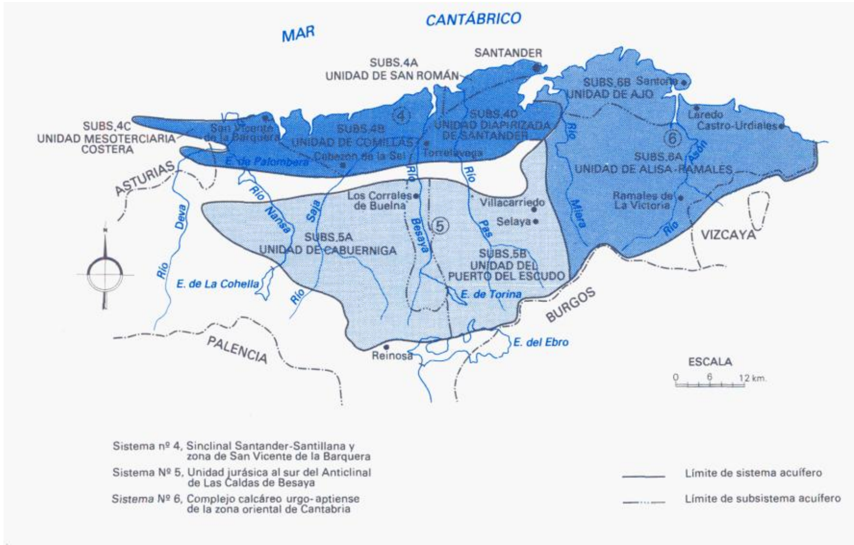


Figure 17. Cantabrian groundwater systems. Source IGME [19].

In all cases the water quality is classified as good or drinking to supply (Hydrogeological Units in Spain, IGME 2012).

Water bodies that depend significantly on the two units affected by the Luena permit are listed below (Table 15).

Table 15. Water bodies dependent on hydrogeologic units affected by the permit Luena. Source [20].

Hydrogeological Unit	Rivers Affected	Marshes Affected
Alisas-Ramales	Asón Gándara Carranza Calera	Marisma de la Ría de Ajo Marisma de Joyel Marisma de Santoña
Puerto del Escudo	Pas Pisueña	

The distribution system of Santander supply which covers the municipalities of Santander, Piélagos, El Astillero, Camargo and Bezana, representing more than 250,000 population, has the following points of capture:

San Martin de Toranzo-La Molina: exploiting groundwater and its outcrops in the valley of Pas, representing a total of 141.94 Hm^3/year, and catchments of Pas and Pisueña rivers [21]

The contamination risks and epistemic uncertainties associated with well casing failure and migration of fluids through fractures are potentially substantial, but minor compared to the contamination risk and epistemic uncertainty associated with disposal of used hydraulic fracturing fluids **[22]**.

Table 16. Comparison of water contamination pathway risk from hydraulic fracturing in a typical Marcellus Shale gas well. Source: [22].

Pathway	Best-Case 50th Percentile Contamination Volume (m^3)	Worst-Case 50th Percentile Contamination Volume (m^3)	Maximum Epistemic Uncertainty Between Best and Worst Case (m^3)
Transportation	< 0.01	0.3	0.6
Well casing failure	< 0.01	9	60
Fracture migration	< 0.01	225	270
Dilling site spills	< 0.01	3	15,000
Wastewater disposal	202	13,500	26,900

The probability bounds constitute the best case (smallest possible contamination) and the worst case (largest possible contamination) for a single well.

The study referenced in **[22]** used publicly available data and estimated where available without inflating the bounds (Table 16). Generally, the best-case boundary showed a contamination probability resulting from the estimates of hydraulic fracturing proponents (e.g., the natural gas drilling industry). Similarly, the worst-case boundary showed a contamination probability resulting from the estimates of hydraulic fracturing opponents (e.g., environmental organizations).

The effects of a potential groundwater contamination are classified as catastrophic because of the sensitive groundwater bodies dependent on hydrogeology units affected, and the drinking supply for more than 250.000 population potentially affected (Table 17). If flow back water is used to make up fracturing fluid, this would increase the risk of introducing naturally occurring chemical contaminants and radioactive materials to groundwater and the risks posed by metals and NORM (radium, thorium and uranium) **[11].**

The probability is occasional (several cases reported) .

Table 17. Risk on groundwater contamination in Luena permit, across all phases

<table>
<tr><th>HAZARD</th><th>PROBABILITY</th><th>RISK</th></tr>
<tr><td>Groundwater bodies: Alisas, Ramales Puerto del Escudo</td><td rowspan="5">Several cases Documented [7]</td><td rowspan="6">VERY HIGH</td></tr>
<tr><td>Sensitive water bodies dependent</td></tr>
<tr><td>European geology more complex</td></tr>
<tr><td>Drinking supply</td></tr>
<tr><td>225 m^3 per well worst case</td></tr>
<tr><td>CATASTROPHIC</td><td>OCCASIONAL</td></tr>
</table>

Thes risk of a wide development of shale gas exploitation over this area is considered to be **VERY HIGH.**

2.1.5. Surface Water Contamination

The operations conducted at individual well pads requires the transport of materials to the site; use of those substances; generation of wastes; storage of wastes; and subsequent transport of wastes generated.

The key operational hazards in these processes at an individual well pad site include (but are not limited to) the following:

1. Spillage, overflow, water ingress or leaching from cutting/mud pits owing:
   - limited storage capacity;
   - operator error;
   - storm water or flood water ingress; or
   - poor construction or failure of pit liner;
1. Spillage of concentrated fracturing fluids during transfer and final mixing operation (with water) that occurs onsite owing to:
   - pipework failure;
   - operator error;
3. Spillage of flowback fluid during transfer to storage owing to:
   - pipework or frac tree failure during the operation;
   - insufficient storage capability and overflow;
   - operator error;
3. Loss of containment of stored flowback fluid owing to:
   - tank rupture;
   - overfilling of lagoons due to operator error or limited storage capacity;
   - water ingress from storm water or floods;
   - poor construction or failure of liner;

4. Spillage of flowback fluid during transfer from storage to tankers for transport owing to:

    - pipework failure; or

    - operator error

5. Spillage of flowback fluid during transport to wastewater treatment works

Given the toxic properties of some fracturing and flowback fluids (or constituents) spillage onto land or surface water is likely to be of concern [7].

Some 15-80% of injected fluid returns to the surface as flowback (and, by implication, 20-85% remains underground). Whilst flowback fluids include the fracturing fluids pumped into the well, it also contains [7]:

- chemical transformation products that may have formed due to reactions between fracturing additives;
- substances mobilised from within the shale formation during the fracturing operation; and
- naturally occurring radioactive materials (NORMs)

The UK Environment Agency (EA) has undertaken a mineral analysis of flowback fluid from exploratory drilling by Cuadrilla Resources (the only shale gas operation that has conducted hydraulic fracturing in the UK to date). The analysis found notably high levels of sodium, chloride, bromide and iron, as well as higher values of lead, magnesium and zinc and elevated levels of chromium and arsenic compared with the local mains water that is used for injecting into the shale. The flowback fluid is very saline with chloride concentration being four times that of seawater [7].

The analysis also showed the presence of low but still significant levels of NORMS with radium 226 as the radioactive material present at the highest levels (between 14 and 90 Becquerel per litre). Other naturally occurring isotopes present included potassium 40 and radium 228 [7].

Volumes of waste generated and associated requirements for storage and industrial waste water treatment are also large [7]. The study states that permit Luena [8] establishes that water will be treated by licensed waste treatment plant or municipal sewage plant in the area. Notice that nowadays legislation don´t permit treatment of industrial wastes on a municipal sewage plant.

We assume 2,9 million gal/well [2] (10.978 m^3), of which 33% [23] is recovered as waste flowback, 3.623 m^3/well.

If these wastes are not reused, the potentially waste waters in Luena permit rises to 1.275.204 m^3 for all the shale gas development.

The AEA study [11] found that there is a high risk of surface contamination in fracturing and well completion stages.

The potentially 50th percentile contamination volume rises to 202-13.500 m^3/well [22] (Table 16).

The area affected by the Luena permit is densely populated by numerous streams and creeks as shown in Figure 18.

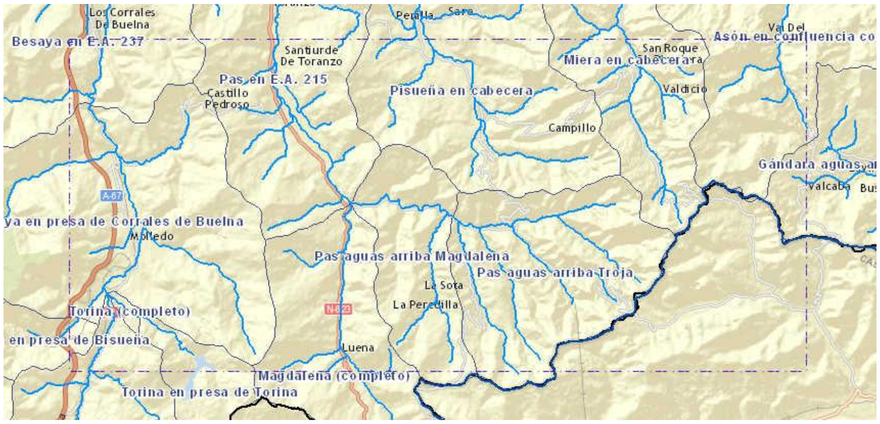


Figure 18. Streams in the Luena Permit. Source GIS of Cantabrian Hydrographic Confederation.

The banks of the Pas are listed for their natural values as LIC No. 1300010 called Pas River. At the same LIC belong the main tributaries of the Pas River.

In view of the risks posed by metals and NORM in waste waters, the potential impacts are judged to be of “major” significance. The probability is judge as “occasional” (Table 18).

Table 18. Risk on surface water contamination in Luena permit, across all phases

HAZARD	PROBABILITY	RISK
3.623 m^3/well waste waters	Several cases Documented [7]	HIGH
1.275.204 m^3 waste waters (full permit), metals, NORM		
Minimum 202 m^3/well, water volume contamination		
Numerous streams and creeks		
LIC Pas River		
High rainfall, risk of rupture or overfilling		
MAJOR	**OCCASIONAL**	

The risk of a wide development of shale gas exploitation over this area is considered to be **HIGH.**

2.1.6. Water Resources Depletion

Large volumes of water are consumed during conventional drilling of the bore hole in order to cool and lubricate the drilling head, but also to remove the drilling mud. About a factor of ten more water is consumed in hydraulic fracturing for the stimulation of the well by injecting over pressurized water for the creation of the cracks.

Wells drilled for producing shale gas may have to be fractured several times over the course of their operation time. Each additional fracture operation may require more water than the previous one. In some cases, the wells are refractured up to 10 times [12].

The water resources depletion for a single well is evaluated by report referenced in [2] to 10,978 m^3, during 5 days of hydraulic fracturing stage [15]. The drinking water supply of Santander, San Martin de Toranzo-La Molina, produce a total of 141.94 Hm^3/year [21]. The water resources depletion for a single well represents 0.56% of the water supply for 5 days.

The average caudal of the Pas River rises to 16.03 m^3/s, but the minimum to 1.07 m^3/s. The water depletion for a well represents 2.37% of this caudal during fracturing stage.

There is potential for adverse effects when water withdrawals occur on low flow or drought conditions or in unsustainable locations [11].

Less affection on resources is expected (Minor), considering it is not likely to match the stages of fracturing on several wells at the same time (because it only lasts 5 days), taking into account not to affect low caudal streams. The probability is judged as occasional (Table 19).

Table 19. Risk on water resources depletion in Luena permit, across all phases

HAZARD	PROBABILITY	RISK
For a single well 2.37% of Pas River caudal during fracturing	Drought periods Not simultaneous	MODERATE
For a single well 0.56% of Santander drinking water supply		
Risk in unsustainable locations		
High rainfall, risk of rupture or overfilling		
MINOR	**OCCASIONAL**	

The risk of a wide development of shale gas exploitation over this area is considered to be MODERATE.

2.1.7. Biodiversity Impacts

Unconventional gas extraction can affect biodiversity in a number of ways. It may result in the degradation or complete removal of a natural habitat through excessive water abstraction, or the splitting up of a habitat as a result of road construction or fencing being erected, or for the construction of the well-pad itself. New, invasive species such as plants, animals or micro-organisms may be introduced during the development and operation of the well, affecting both land and water ecosystems [11]

Well drilling could potentially affect biodiversity through noise, vehicle movements and site operations. The treatment and disposal of well drilling fluids also need to be adequately handled to avoid damaging natural habitats. However, these risks are lower than during other stages of shale drilling **[11]**

During hydraulic fracturing, the impacts on ecosystems and wildlife will depend on the location of the well-pad and its proximity to endangered or threatened species. Sediment runoff into streams, reductions in stream flow, contamination through accidental spills and inadequate treatment of recovered waste-waters are all seen as realistic threats as is water depletion **[11]**

However, the study found that the occurrence of such effects was rare and cumulatively the risks could be classified as moderate.

Effects on natural ecosystems during the gas production phase may arise due to human activity, traffic, land-take, habitat degradation and fragmentation, and the introduction of invasive species. Pipeline construction could affect sensitive ecosystems and re-fracturing would also cause continuing impacts on biodiversity. The possibility of land not being suitable for return to its former use after well abandonment is another factor potentially affecting local ecosystems. Biodiversity risks during the production phase were considered to be potentially high for multiple installations **[11]**

The Luena permit affects four protected areas:

- LIC Montaña Oriental.
- Parque Natural de los Collados del Asón.
- LIC Sierra del Escudo.
- LIC Río Pas.

Although it is not possible to develop fracking activity in protected areas, they may be affected by the proximity of the works. Particular relevance has the possible affection of the Pas River LIC including all margins of its tributary streams.

Table 20. Risk on biodiversity in Luena permit, across all phases

HAZARD	PROBABILITY	RISK
Protected areas affected: • LIC Montaña Oriental • LIC Sierra del Escudo • LIC Río Pas • Parque Natural de los Collados del Asón	Could potentially occur under foreseeable future circumstances	**HIGH**
MODERATE	**OCCASIONAL**	

Thes risk of a wide development of shale gas exploitation over this area is considered to be **HIGH** (Table 20).

2.1.8. Traffic Impacts

Total truck movements during the construction and development phases of a well are estimated at between 7,000 and 11,000 for a single ten-well pad. These movements are temporary in duration but would adversely affect both local and national roads and may have a significant effect in densely populated areas. These movements can be reduced by the use of temporary pipelines for transportation of water.

During the most intensive phases of development, it is estimated that there could be around 250 truck trips per day onto an individual site – noticeable by local residents but sustained at these levels for a few days. The effects may include increased traffic on public roadways (affecting traffic flows and causing congestion), road safety issues, damage to roads, bridges and other infrastructure, and increased risk of spillages and accidents involving hazardous materials. The risk is considered to be moderate for an individual installation, and high for multiple installations **[11].**

Assuming an average number of trips per well of 900, a total of 316,800 truck trips would occur in the total development of the Luena permit. This can be a very important impact on noise, environment and road maintenance, considering the secondary road network (with little traffic) involved (Table 21).

Table 21. Risk on traffic in Luena permit, across all phases

<table>
<tr><th>HAZARD</th><th>PROBABILITY</th><th>RISK</th></tr>
<tr><td>900 trips for a single well construction and development (drilling and fracturing)</td><td rowspan="4">Occurs several times A year</td><td rowspan="5">HIGH</td></tr>
<tr><td>More trips for gas transportation (production)</td></tr>
<tr><td>Secondary road network</td></tr>
<tr><td>Risk of accidents with hazardous chemicals</td></tr>
<tr><td>MODERATE</td><td>LONG TERM DEFINITE</td></tr>
</table>

The risk of a wide development of shale gas exploitation over this area is considered to be HIGH**.**

2.1.9. Visual Impacts

In terms of visual impacts, each well pad will be around 1ha in size and will be equipped with access roads. During construction well pads may comprise storage pits, tanks, drilling equipment, trucks, etc. making the installations difficult to develop in a way that is sympathetic with surrounding landscapes **[7]**.

Given that 58 well pads would be required, assuming 6 wells per pad, it is likely that in a rural context visual impacts will be contentious (Table 22).

Visual impact is evaluated as moderate during fracturing and low in production, in the report of the European Commission, 2012 **[11]**.

Table 22. Risk on visual impacts in Luena permit, across all phases

HAZARD	PROBABILITY	RISK
58 well pads estimated (6 wells per pad)	Continuous	**MODERATE**
Rural environment		
Symbolic landscapes		
SLIGHT	**LONG TERM DEFINITE**	

Thes risk of a wide development of shale gas exploitation over this area is considered to be MODERATE.

2.1.10. Seismicity

New York State DEC 2011 PR (page 6-319) describes two types of induced seismic events associated with hydraulic fracturing. One is micro-seismic events resulting from the physical fracturing process. These are sufficiently small to require very sensitive monitoring equipment to be detected **[15]**.

The second type of event, results from injection fluids reaching existing geological faults, leading to more significant ground accelerations, potentially felt by humans at the ground surface. These types of events can arise in any process involving the injection of pressurised liquids underground. For example, New York State DEC 2011 PR (page 6-321) notes that carbon sequestration can cause such events, with magnitudes typically less than 3, and the events connected to circumstances that could be avoided through site selection and injection design.

Cantabria has been considered as inactive, from a tectonic point of view. Nevertheless, recent studies (González-Díez,1995; González-Díez et al., 1996a,b, 1999) have shown that seismic activity (with magnitudes over 4.0) has been registered from the Upper Pleistocene–Holocene. The earthquake epicentres (Figure 19) are linked to some faults mapped in this region ("Frente Cabalgante de El Escudo de Cabuérniga" fault and "Selaya-Arredondo" fault). These faults have conditioned the occurrence of landslides and the development of the bordering fluvial deposits. However, less than five earthquakes (all of then with magnitudes less than 3.0) have been registered in the region during the last 10 years. Taking into account all these data, one can say that Cantabria is, therefore, an example of an area of mid-low seismic activity **[24]**

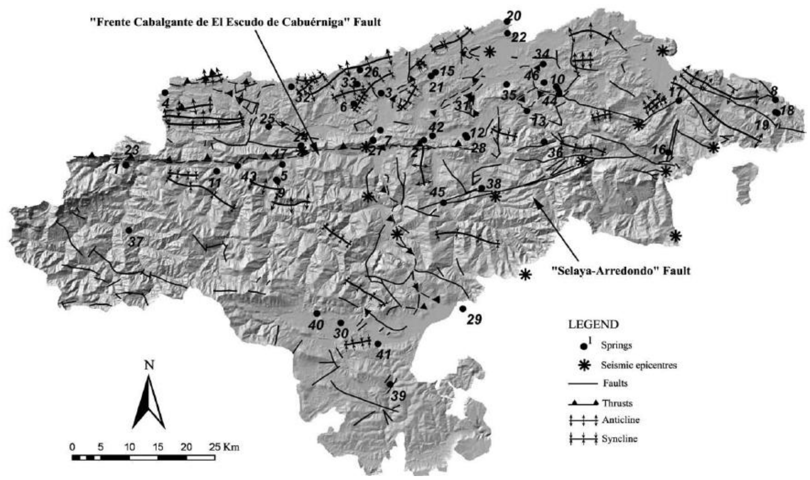


Figure 19. Spatial distributions of the springs analyzed (radon associated with latent faults, main structural features and seismic epicenters [24]

In the area affected by the permit area Luena González-Díez **[24]** has identified two springs associated with latent failures (Selaya-Arredondo Fault), as showed in Figure 19: 27- Las Caldas (outside the permit, but near it), 38- Tezanos, 45- Alceda.

Table 23. Risk on seismicity in Luena permit, across all phases

HAZARD	PROBABILITY	RISK
Selaya-Arredondo fault potentially affected	Several cases related to fracturing stage	MODERATE
Earthquakes with magnitudes less than 3.0 registered		
Possibility of fault reactivation		
Surface damage improbable, but social alert		
MINOR	**OCCASIONAL**	

The risk of a wide development of shale gas exploitation over this area is considered to be MODERATE (Table 23).

2.2. ECONOMIC FACTORS

2.2.1. Profitability

In Europe the strata of rock have, over the eras, folded back on themselves creating faults that complicate the drilling and appraisal process. While Europe's gas distribution infrastructure is well developed, the services sector that would support an unconventional gas industry is not, Europe also lacks suitable technical equipment, such as drilling rigs.

Given the infancy of the sector in Europe, we can expect initial production costs to be much higher; drilling costs for Europe are currently between two to four times more expensive on a unit cost basis than they are in North America.

Several experts indicate that the overwhelming factor influencing the break-even prices of unconventional gas is the initial well cost – drilling and completion – rather than royalty rates or operating cost **[25]**

2.2.1.1. Costs in Luena permit

a) Land: In Spain, unlike in EE.UU. existing underground resources belong to the State. The exploitation of them is considered a public utility, allowing the expropriation of land. Therefore, no royalties or land acquisition are paid to land owner.

b) Capital expenditures (CAPEX)

Consultation of publications "Joint association survey on drilling costs" and others authors and companies, shows that the average cost of a deep well can be completed, for the EE.UU. and Canada in a range of 6 to 9 MUS $ including various stimulation intervals. As a counterpoint to the cost of a well in Spain today, including stimulation completed various intervals, may be around 25 MM €, i.e. about 3.5 to 5 times. **[4].** Table 24 shows average well cost of a well in some European countries.

c) Operating expenditures (OPEX)

Lease operating expenses are those costs associated with work physically performed at the work site or specifically and exclusively for operations (direct cost).

Operating costs vary between leases and with the inventory of producing wells, and change with commodity prices (lease fuel, production taxes); age (chemical treatment and monitoring, corrosion and scale); the number and type of wells and surface facilities; product stream and volume; gathering system mileage; water production and disposal; and well servicing requirements.

Table 24. Selected rates European shale gas basins. Source [3]

	Alum Sweden	Silurian Poland	Posidonia Germany	Shale Austria	Shale Turkey
EUR/Well (Bcf-25 years)[a]	3.25	3.25	3.25	6.55	1.97
Productivity year 1 flow rate (bcf/year)[a]	0.50	0.50	0.50	1.00	0.30
Well CAPEX ($/MM)[b]	15	14	13	24.5	8.1
OPEX ($/Mcf)[b]	0.6	0.5	0.6	0.4	1.2
Other OPEX ($/Mcf)[b]	1.4	1.0	1.2	1.0	1.0
Royalty rate (%)[b]	0	1.5	8	10	13
Corporate tax (%)[b]	28	19	30	25	20
Depreciation (%)[c]	10	10	10	10	10
Discount rate (%)[c]	5	5	5	5	5

d) Taxes

In the EEUU gas wells that produce more than an average monthly rate of 250 Mcfd are charged a severance tax that is adjusted annually for the 12-month period ending June 30 of each year. Severance tax rates are correlated with gas price. In Spain general taxes for this sector are established in 40%.

2.2.1.2. Profitability analysis

Data calculation:

Capital expenditures (MM$)	10-25
Productivity year 1 (bcf)	0.5- 3.28bcf (total 25 yr.)
Gas price	6-11 $/Mcf
Operating cost	0,5-4$/Mcf
Operating cost Esc	1%/yr.
Discount factor	5%

Depreciation of equipment was performed using the number system digit declining for 10 years. Tax losses have been offset by 50% over the next 18 years (under current legislation). Gas price in Europe is based on World Bank projections.

Table 25. Gas natural price forecast in nominal US Dollars. Source: World Bank (http://siteresources.worldbank.org/INTPROSPECTS/Resources/334934-1304428586133/Price_Forecast.pdf)

		Actual						Forecast								
Commodity	Unit	1980	1990	2000	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2025
Energy																
Coal, Australian	$/mt	40.1	39.7	26.3	99.0	121.4	96.4	93.0	91.0	90.0	91.0	91.9	92.9	93.9	94.9	100.0
Crude oil, avg, spot	$/bbl	36.9	22.9	28.2	79.0	104.0	105.0	102.0	102.2	102.1	101.9	101.7	101.5	101.4	101.2	101.5
Natural gas, European	$/mmbtu	4.2	2.8	3.9	8.3	10.5	11.5	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.0
Natural gas, US	$/mmbtu	1.6	1.7	4.3	4.4	4.0	2.8	3.5	4.0	4.5	5.0	5.3	5.5	5.8	6.0	7.0
LNG, Japanese	$/mmbtu	5.7	3.6	4.7	10.8	14.7	16.7	16.0	15.5	15.0	14.8	14.5	14.3	14.0	13.8	12.5

Gas production declining curve is calculated on the base of the following exponential function [3]:

$$q_n = q_i \cdot (1+a)^n$$

Where q_n is the flow rate in year n, qi the starting flow rate in first year, "a" the annual decline rate (-0.15), and "n" the number of years (Figure 20).

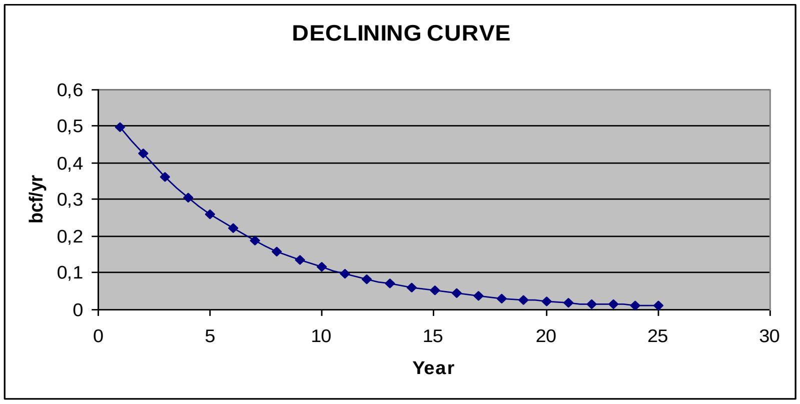


Figure 20. Gas production declining curve.

A) EVALUATING CAPEX (Table 26, Figure 21)

EUR(bcf)	3,28
Gas price ($/MMBTU)	10 (Table 25)
Operating cost ($/Mcf)	1,5
DISCOUNT TAX	5
CAPEX	VARIABLE

Table 26. Sensitivity analysis. Capital cost variation (CAPEX)

CAPEX (MM$)	NPV ($)	IRR(%)	PAYBACK(Years)
25	-4.472.404	1,14	15
20	55.387	5,06	8
15	4.185.504	10,93	5
10	8.315.621	22,34	3

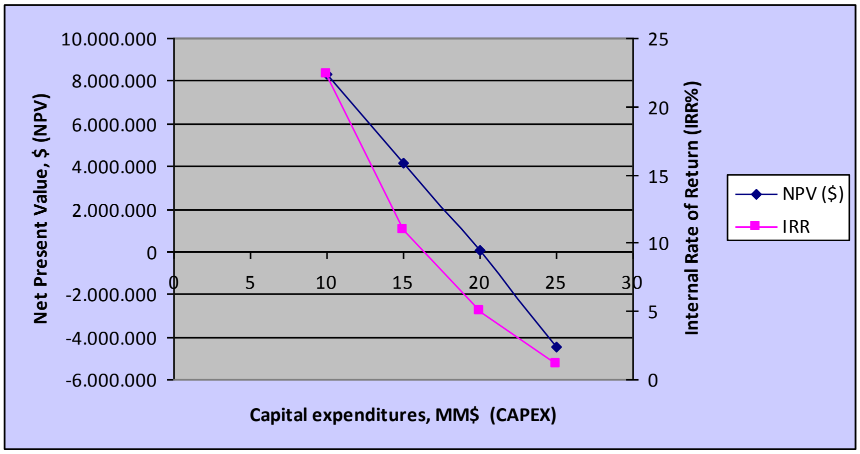


Figure 21. Sensitivity analysis. Capital cost variation (CAPEX).

B) EVALUATING GAS PRICE (Table 27, Figure 22)

EUR(bcf)	3,28
CAPEX (MM$)	15
Gas price ($/MMBTU)	VARIABLE
Operating cost ($/Mcf)	1,5
DISCOUNT TAX	5

Table 27. Sensitivity analysis. Gas price.

GAS PRICE ($/MMBTU)	NPV ($)	IRR(%)	PAYBACK(Years)
6	-4.118.963	-0,91	26
8	255.564	5,37	8
10	4.185.504	10,93	5
11	6.150.473	13,66	5

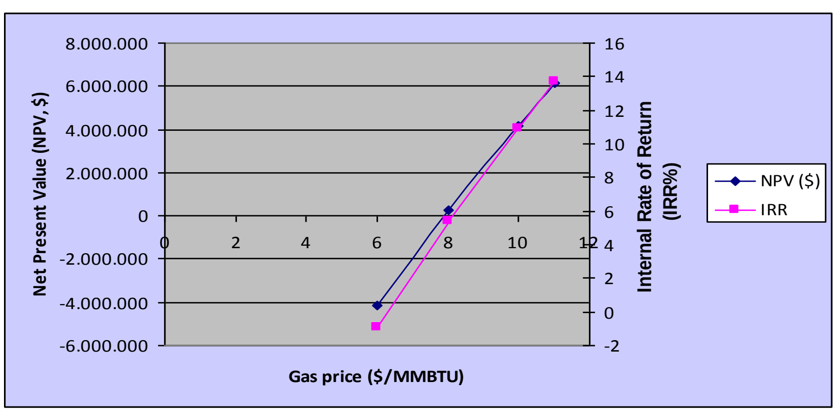


Figure 22. Sensitive Analysis. Gas price.

C) EVALUATING OPEX (Table 28, Figure 23)

EUR(bcf)	3,28
CAPEX (MM$)	15
Gas price ($/MMBTU)	10
Operating cost ($/Mcf)	VARIABLE
DISCOUNT TAX	5

Table 28. Sensitivity analysis. Operation Expenditures (OPEX).

OPEX ($/Mcf)	NPV ($)	IRR(%)	PAYBACK(Years)
0,5	6.234.733	13,74	5
1	5.210.118	12,34	5
1,5	4.185.504	10,93	5
2	3.160.889	9,51	6
3	1.111.660	6,61	7
4	-978.351	3,56	9

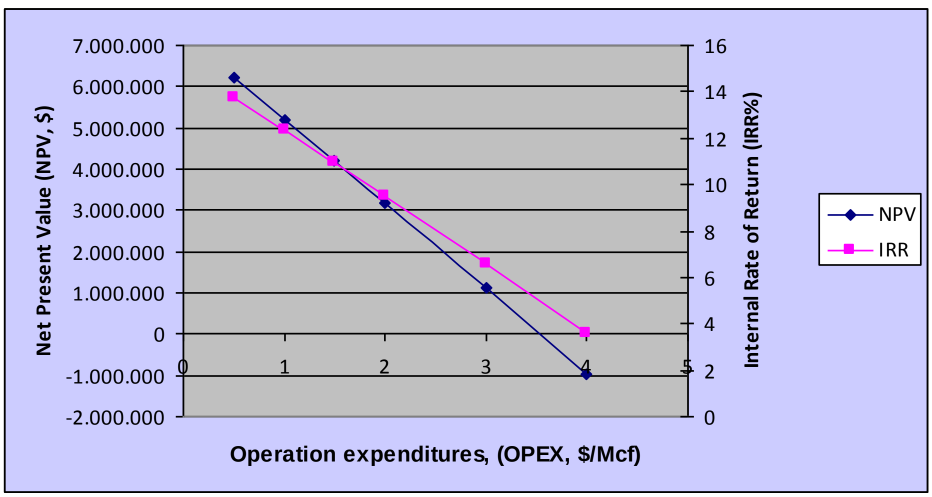


Figure 23. Sensitivity analysis. Operation Expenditures (OPEX).

Considering a minimum internal rate of return of 10% to be feasible, the following conditions must be met:

- The capital cost (CAPEX) should be located in the vicinity of $ 15MM.

- With a capital cost of $ 15MM:
  - Gas prices should not drop $ 9 / MMBtu.
  - Operating costs (OPEX) must not exceed $ 2 / Mcf.

Economic assessment worksheets available in Annex 5.2.

2.2.2. Other economic impacts (Table 29)

- Assuming capital costs more likely in the future development of fracking, of $ 15MM, public Income tax per well amount to $ 2,641,090.
- Assuming an average number of trips per well of 900, this can be a very important economic impact on road maintenance as seen in section 3.1.8.
- Loss of properties value. The presence of oil and gas facilities can have significant negative impacts on the values of neighbouring rural residential properties. At the mean level of industry facilities within 4 km, property values are estimated to be reduced between 4 and 8 percent **[26]**.
- Applying a loss in value of 8% in rural and urban properties, and based on the catastral value (ICANE 2013), a loss of USD 53MM is obtained.
- Due to the small number of tourist establishments in the area, the impact on tourism sector is limited.
- The main industry in the area is livestock. With 44,792 head of cattle, besides sheep and goats (ICANE 2012), it is important to deepen on the study of potential affection in livestock of shale gas development in this area.

It should be noted again the negative effect of public nature of resources (in Spain), on the local economy, with extremely low rates for concession granted. In other countries, companies must pay royalties on the ground and the amount of extracted gas.

Table 29. Economic factors resume.

Positive	Negative
-4.5 to 8.3 MM$ NPV /well (CAPEX decisive on profitability)	Loss of properties value 53MM$
Public income tax 2.6 MM$ /well	Impact tourism limited
	Possible impact on local economy-livestock?
	Not expected important local land acquisition incomes (public resources)

2.3. SOCIAL FACTORS

2.3.1. Employment

A key reason for the shale gas industry's profound economic impacts its high "employment multiplier" – the indirect and induced jobs created to support the industry. For every direct job created in the shale gas sector, more than three indirect and induced jobs are created **[2]**

Reports suggest that many of these jobs are temporary and frequently go to out-of-state workers**[27]**

Further, economic modelling has shown that for each million dollars spent on energy production in the United States, wind and solar create 9.5 and 9.8 direct and indirect jobs, respectively, compared to only 3.7 jobs for oil and gas **[27]**

Table 30. Summary of five studies about the impact of shale gas on employment [2]

Researchers	Shale play	Main conclusion
CBER, Ref. [261]	Marcellus Shale in Arkansas	Shale gas extraction is estimated to increase gross revenues in the state of Arkansas by $2.6 billion and generate 9533 jobs in 2007
Considine et al., Ref. [259]	Marcellus Shale in western and northern Pennsylvania	The shale gas extraction industry is responsible for $2.263 billion in economic activity, the creation of 29,284 jobs, and the payment of $238.5 million in state and local taxes within the Pennsylvania in 2008
Considine et al., Ref. [262]	Marcellus Shale in western and northern Pennsylvania	(i) The shale gas industry is estimated to have contributed 44,098 jobs to the Pennsylvania economy and paid $389 million in state and local taxes in 2009. (ii). The economic impact of the shale gas industry is expected to $18.85 billion in value added, $1.87 billion in state and local taxes, and nearly 212,000 jobs by 2020
The Permanent Group, Ref. [263]	Barnett in Dallas/Ft. Worth Area	(i) The economic effects of Barnett Shale activity in 2006 was $6.1 billion in annual output and 60,820 jobs. (ii) The economic effects of Barnett Shale activity in 2007 was $8.4 billion in output and 83,823 positions. (iii) The economic effects of Barnett Shale activity in 2008 are even higher than in years past, with incremental output of $11.0 billion and 111,131 jobs
Scott, Ref. [264]	Haynesville in Louisiana	It was estimated that the extraction activity of these seven firms generated approximately $2.4 billion in new business sales within the state of Louisiana in 2008

If the shale gas sector requires special skills that local residents lack and are costly to acquire, then workers would have to come outside the community. As skilled workers move to the community, total income generated increases. Per capita income would also likely increase, either because of rising wages across sectors or because the newly created jobs are higher skilled and therefore higher paying jobs. Even if people living below the poverty line lack the skills to find jobs in the shale gas sector, spill-overs into sectors like service (e.g. hotels and restaurants) would increase employment and perhaps wages for low income persons **[28]**

The results suggest that each million dollars in gas production created 2.35 jobs in the county of production **[28]**.

Whereas in 2010, 60.820 jobs (Table 30) **[2]** (direct and indirect) in the Barnett (USA) were created, with 4000 wells drilled (15.2 jobs / well), extrapolating to this case, it would create more than 5,000 jobs, during the period of Luena permit complete development. Most of them would be temporary.

Given that unemployment in permit Luena municipalities rises to 937 people (ICANE May 2014), it would expect that many of them would find a job in fracking development on the area.

2.3.2. Health Effects

Possible health effects are mainly caused by the impacts of the relevant emissions into air or water. These are predominantly headache and long-term effects from volatile organic compounds. Groundwater contamination may be dangerous when inhabitants come into contact with contaminated water. For instance, when small children are frequently washed with contaminated water this may have an effect on allergies and health. Also, wastewater pits and blow out fluids are a matter of concern when the skin is exposed **[12]**.

Research described in paper "Human health risk assessment of air emissions from development of unconventional natural gas resources" **[29]** used standard United States Environmental Protection Agency (EPA) methodology (Table 31) to estimate non-cancer HIs and excess lifetime cancer risks for exposures to hydrocarbons using residential exposure scenarios developed for the NGD (natural gas development) project. We used air toxics data collected in Garfield County from January 2008 to November 2010 as part of a special study of short term exposures as well as on-going ambient air monitoring program data to estimate subchronic and chronic exposures and health risks **[29]**

The GCPH -Garfield County Department of Public Health- collected the samples from a fixed monitoring station and along the perimeters of four well pads and shipped samples to Eastern Research Group for analysis of 78 hydrocarbons using EPA's compendium method TO-12, Method for the Determination of Non- Methane Organic Compounds in Ambient Air Using Cyrogenic Preconcentration and Direct Flame Ionization Detection **[29]**

The results (Table 34) indicate that:

NON CANCER RISK (CHRONIC, 30 YEARS-SUBCHRONIC 20 MONTHS)

Residents living ≤½ mile from wells are at greater risk for health effects from NGD than are residents living >½ mile from wells. Subchronic exposures to air pollutants during well completion activities present the greatest potential for health effects. The subchronic non-cancer hazard index (HI) of 5 for residents ≤½ mile from wells was driven primarily by exposure to trimethylbenzenes, xylenes, and aliphatic hydrocarbons. Chronic HIs were 1 and 0.4. for residents ≤½ mile from wells and >½ mile from wells, respectively (table 32)

To evaluate subchronic non-cancer HIs from well completion emissions, we estimated that a resident lives ≤½ mile from two well pads resulting a 20-month exposure duration based on 2 weeks per well for completion and 20 wells per pad, assuming some overlap in between activities. The subchronic exposure concentrations for this population were the 95% UCL on the mean concentration and the median concentration from the 24 well completion samples. (Table 32)

CANCER RISK (CHRONIC 30 YEARS)

Cumulative cancer risks were 10 in a million and 6 in a million for residents living ≤½ mile and >½ mile from wells, respectively, with benzene as the major contributor to the risk (table 33)

Risk management approaches should focus on reducing exposures to emissions during well completions.

Table 31. Chronic and subchronic concentrations, critical effects, and major effects for hydrocarbons in quantitative risk assessment. Source: [29].

Hydrocarbon	Chronic		Subchronic		Critical effect/ target organ	Other effects
	RfC (μg/m^3)	Source	RfC (μg/m^3)	Source		
1,2,3-Trimethylbenzene	5.00E+00	PPTRV	5.00E+01	PPTRV	Neurological	Respiratory, hematological
1,3,5-Trimethylbenzene	6.00E+00	PPTRV	1.00E+01	PPTRV	Neurological	Hematological
Isopropylbenzene	4.00E+02	IRIS	9.00E+01	HEAST	Renal	Neurological, respiratory
n-Hexane	7.00E+02	IRIS	2.00E+03	PPTRV	Neurological	–
n-Nonane	2.00E+02	PPTRV	2.00E+03	PPTRV	Neurological	Respiratory
n-Pentane	1.00E+03	PPTRV	1.00E+04	PPTRV	Neurological	–
Styrene	1.00E+03	IRIS	3.00E+03	HEAST	Neurological	–
Toluene	5.00E+03	IRIS	5.00E+03	PPTRV	Neurological	Developmental, respiratory
Xylenes, total	1.00E+02	IRIS	4.00E+02	PPTRV	Neurological	Developmental, respiratory
n-propylbenzene	1.00E+03	PPTRV	1.00E+03	Chronic RfC PPTRV	Developmental	Neurological
1,2,4-Trimethylbenzene	7.00E+00	PPTRV	7.00E+01	PPTRV	Decrease in blood clotting time	Neurological, respiratory
1,3-Butadiene	2.00E+00	IRIS	2.00E+00	Chronic RfC IRIS	Reproductive	Neurological, respiratory
Propylene	3.00E+03	CalEPA	1.00E+03	Chronic RfC CalEPA	Respiratory	–
Benzene	3.00E+01	ATSDR	8.00E+01	PPTRV	Decreased lymphocyte count	Neurological, developmental, reproductive
Ethylbenzene	1.00E+03	ATSDR	9.00E+03	PPTRV	Auditory	Neurological, respiratory, renal
Cyclohexane	6.00E+03	IRIS	1.80E+04	PPTRV	Developmental	Neurological
Methylcyclohexane	3.00E+03	HEAST	3.00E+03	HEAST	Renal	–
Aliphatic hydrocarbons C_5–C_8[a]	6E+02	PPTRV	2.7E+04	PPTRV	Neurological	–
Aliphatic hydrocarbons C_9–C_{18}	1E+02	PPTRV	1E+02	PPTRV	Respiratory	–
Aromatic hydrocarbons C_9–C_{18}[b]	1E+02	PPTRV	1E+03	PPRTV	Decreased maternal body weight	Respiratory

Abbreviations: 95%UCL, 95% upper confidence limit; CalEPA, California Environmental Protection Agency; HEAST, EPA Health Effects Assessment Summary Tables 1997; HQ, hazard quotient; IRIS, Integrated Risk Information System; Max, maximum; PPTRV, EPA Provisional Peer-Reviewed Toxicity Value; RfC, reference concentration; μg/m^3, micrograms per cubic meter. Data from CalEPA 2011; IRIS (US EPA, 2011); ORNL 2011.

[a] Based on PPTRV for commercial hexane.

[b] Based on PPTRV for high flash naphtha.

Table 32. Chronic and subchronic hazard quotients and hazard indices residents living >½ mile from wells and residents living ≤½ mile from wells. Source: [29].

	> ½ mile		> ½ mile	
HI Type	**Chronic HQ**	**Subchronic HQ**	**Chronic HQ**	**Subchronic HQ**
Total Hazard Index	4E-01	2E-01	**1E+00**	**5E+00**
Neurological Effects HI[a]	3E-01	8E-02	9E-01	**4E+00**
Respiratory Effects HI[b]	2E-02	2E-01	7E-01	**2E+00**
Hematogical Effects HI[c]	1E-01	4E-02	5E-01	**3E+00**
Development Effects HI[d]	7E-02	3E-02	3E-01	**1E+00**

HQ based on 95%UCL of median concentration , (95% upper confidence limit; HQ, hazard quotient)

a Sum of HQs for hydrocarbons with neurological effects: 1,2,3-Trimethylbenzene, 1,2,4-Trimethylbenzene, 1,3,5-Trimethylbenzene, 1,3-butadiene, benzene, cyclohexane, ethylbenzene, isopropylbenzene, n-hexane, n-nonane, n-pentane, n-propylbenzene, styrene, toluene, xylenes, aliphatic C5–C8 hydrocarbons.

b Sum of HQs for hydrocarbons with respiratory effects: 1,2,3-Trimethylbenzene, 1,2,4-Trimethylbenzene, 1,3-butadiene, ethylbenzene, isopropylbenzene, n-nonane, propylene,
toluene, xylenes, aliphatic C9–C18 hydrocarbons, aromatic C9–C18 hydrocarbons.

c Sum of HQs for hydrocarbons with hematological effects: 1,2,3-trimethylbenzene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene.

d Sum of HQs for hydrocarbons with developmental effects: benzene, cyclohexane, toluene, and xylenes.

Table 33. Excess cancer risk for residents living >1/2 mile from wells and living ≤1/2 mile. Source: [29].

Hydrocarbon	Unit Risk (µg/m^3)	Source	> ½ mile cancer risk	≤ ½ mile cáncer risk
1,3-Butadiene	3.00E-05	IRIS	5.73E-07	6.54E-07
Benzene	7.80E-06	IRIS	5.4E-06	8.74E-06
Ethylbenzene	2.50E-06	CalEPA	4.26E-07	3.48E-06
Styrene	5.00E-07	CEP	2.70E-08	9.30E-08
Cumulative cancer risk			**6E-06**	**1E-05**

Cancer risk based on 95%UCL of median concentration , (95% upper confidence limit)

Abbreviations: CalEPA, California Environmental Protection Agency; CEP, (Caldwell et al., 1998); IARC, International Agency for Research on Cancer; IRIS, Integrated Risk Information System; Max, maximum; NC, not calculated; WOE, weight of evidence; µg/m3, micrograms per cubic meter. Data from CalEPA 2011; IRIS(US EPA, 2011).

Table 34. Social factors resume.

Positive	Negative
Average 15.2 jobs direct&indirect per well 5,000 new jobs (complete permit development),	Most employment temporary Workers with special skills. Probably from outside the community
	Possible health effects: headache
	Residents living ≤½ mile from wells are at greater risk for health effects (cancer) than residents living >½ mile from wells Social rejection, extensive to the affected municipalities

3. CONCLUSIONS

This study has established a guide for the strategic environmental assessment on hydraulic fracturing. Environmental risks associated with this technology, impacts on local economy, and health effects have been evaluated.

The economic benefit on the development of Luena permit is controlled by the evolution of this technology in Europe that must get down capital costs nowadays, to make it profitable.

The value of gas extracted would suppose a regional gross domestic product increase of 3,654MM$ during the whole permit development. Employment created, would be about 5,000 jobs (took them into account within several decades), most of them temporary and to come outside the community.

In contrast, the impact on environmental burdens is severe, but on land-take and groundwater pollution, impact is considered critic. Land take supposes a strongly modification of a singular territory, of high agricultural natural and symbolic value to society of Cantabria.

On the other hand, social rejection is extensive to the affected municipalities, with the approval of motions of rejection to fracking, and Regional Government passing a Law that prohibits fracking in the region.

The investment that will be realized in Luena research permit rises to 30 MM Euros, and the environmental impact that supposes the construction of the first exploratory well would not justify itself if the strategic environmental assessment determines that fracking is not compatible with conservation of environmental and cultural values of territory.

Decision making must consider these aspects, in the environmental evaluation of plans and programs context, so that, this should be realized in the early stages of any project before any decision is taken.

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FIGURES

TABLES

5. ANNEXES

5.1. REGULATORY FRAMEWORK

European Scope

At European level there is no Framework Directive that regulates mining.

The following Directives are related to fracking activity:

- Directive 94/22/EC of the European Parliament and the Council of 30 May 1994 on the conditions for granting and using authorizations for the prospection, exploration and production of hydrocarbons.
- **Directives on safety and health of workers.**
- **Environmental regulations:**
  - Directive 2006/21/EC of the European Parliament and the Council of 15 March 2006 on the management of waste from extractive industries.
  - Directive 2011/92/EU of the European Parliament and the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment.
  - 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.
  - Council Directive 92/43/CEE of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.
  - Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy.
  - Directive 2006/118/EC of the European Parliament and of the Council on the protection of groundwater against pollution and deterioration.
  - Directive 2002/49/EC of the European Parliament and of the Council relating to the assessment and management of environmental noise.

- **Legislation on chemicals.**

    - 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).

    - 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.

- **Industrial Safety and environmental responsibility.**

    - Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances (SEVESO II).

    - Directive 2004/35/CE of the European Parliament and of the Council on environmental liability with regard to the prevention and remedying of environmental damage.

State Scope

- **Sectoral regulatory regime.**

    - Act 34/1998 of 7 October, on the hydrocarbon sector.

    In Section II exploration, research and exploitation of hydrocarbons is regulated. Resources have demanial character. Permit exploration or exploitation concession is required.

    Regional governments are competent in granting license to prospect for hydrocarbons in its territory.

    Central Government is the competent authority in granting exploration permits covering more than one region. It is also the competent authority in the granting of operating concessions regardless of territory.

        - Hydrocarbon Law is amended to include hydraulic fracturing through the following law :

    Act 17/2013, of 29 October, for the security of supply and increased competition in non-mainland electricity systems.

- **Environmental regulations.**

  - Act 21/2013 of 9 December of environmental assessment.
  - Royal Legislative Decree 1/2001 of 20 July, that approves the revised text of the Water Act.
  - Royal Decree 1514/2009, of 2 October, on the protection of groundwater against pollution and deterioration.
  - Royal Decree 975/2009 of 12 June on the management of waste from extractive industries and the protection and rehabilitation of areas affected by mining activities, and its modification by RD 777/2012.
  - Act 42/2007, of 13 December, of natural heritage and biodiversity.
  - Act 37/2003, of 17 November, of Noise.

- **Legislation on chemicals.**

  - Royal Decree 1054/2002 of 11 October, by which the evaluation process for the registration, licensing and marketing of biocides is regulated.

- **Industrial Safety and environmental responsibility.**

  - Law 21/1992 of July 16, on Industry, amended by Act 25/2009, of 22 December, amending various laws to adapt to the law on free access to activities and its exercising.
  - Royal Decree 2200/1995 of 28 December, approving the Regulations Infrastructure for Quality and Industrial Safety, amended by RD 411/1997, R.D. 338/2010 and R. D. 1715/2010.
  - Royal Decree 1254/1999 of 16 July, that approves the control measures for risks of major accidents involving dangerous substances.
  - Act 26/2007, of 23 October, on Environmental Responsibility.

Regional Scope

- Cantabria Act 17/2006 of 11 December on Integrated Environmental Control.

- Cantabria Act 1/2013, of 15 April, by which regulates the prohibition on the territory of the Autonomous Community of Cantabria the technique of hydraulic fracturing as a technique for research and unconventional gas extraction.

Local Scope

- Act 7/1985 of 2 April, regulating the bases of local regime, regulating the activity license and construction permit.

- Act 14/1986 of 25 April, of General Health, that commits to the municipalities the sanitary control of the environment.

5.2. ECONOMIC ASSESSMENT WORKSHEETS

5.3. UNIT EQUIVALENCES

ENGLISH UNITS	METRIC UNITS
1 Square Mile (Mi^2)	2.59 km^2
1,000 cubic feet (cf)	28.3 m^3
1 Bcf=10^9 cf	
1 MM=10^6	
1 MM Btu=1,000 cf of gas = 28.3 m^3 of gas	
1 m^3 of gas = 11.63 kwh	
1 MMt of Liquefied Natural Gas (LNG) = 1.37 Bcm of natural gas	