GAZ DE SCHISTE

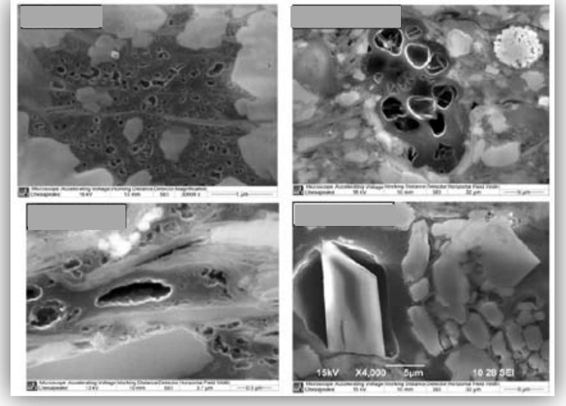
QUELS DÉFIS POUR L'INDUSTRIE ?

Bruno COURME – LIED – 2 avril 2013

NATURAL GAS TRAPPED IN A LOW-PERMEABILITY ROCK

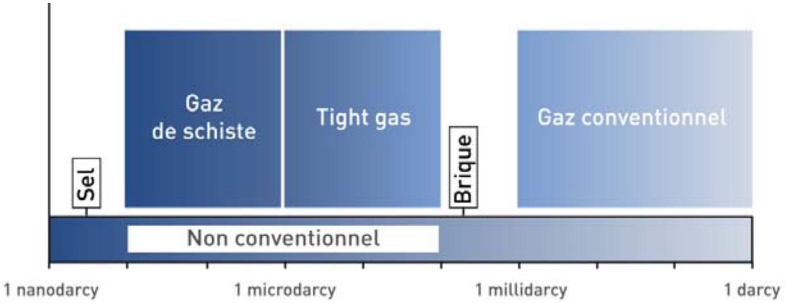
- Shale gas is generated through burial of argillaceous sediments, rich in organic matter, where it remained trapped.

- It is mostly made of methane.



Shale gas and natural gas differ neither in their origin nor in their nature.

- **Permeability of these rocks is extremely low.**



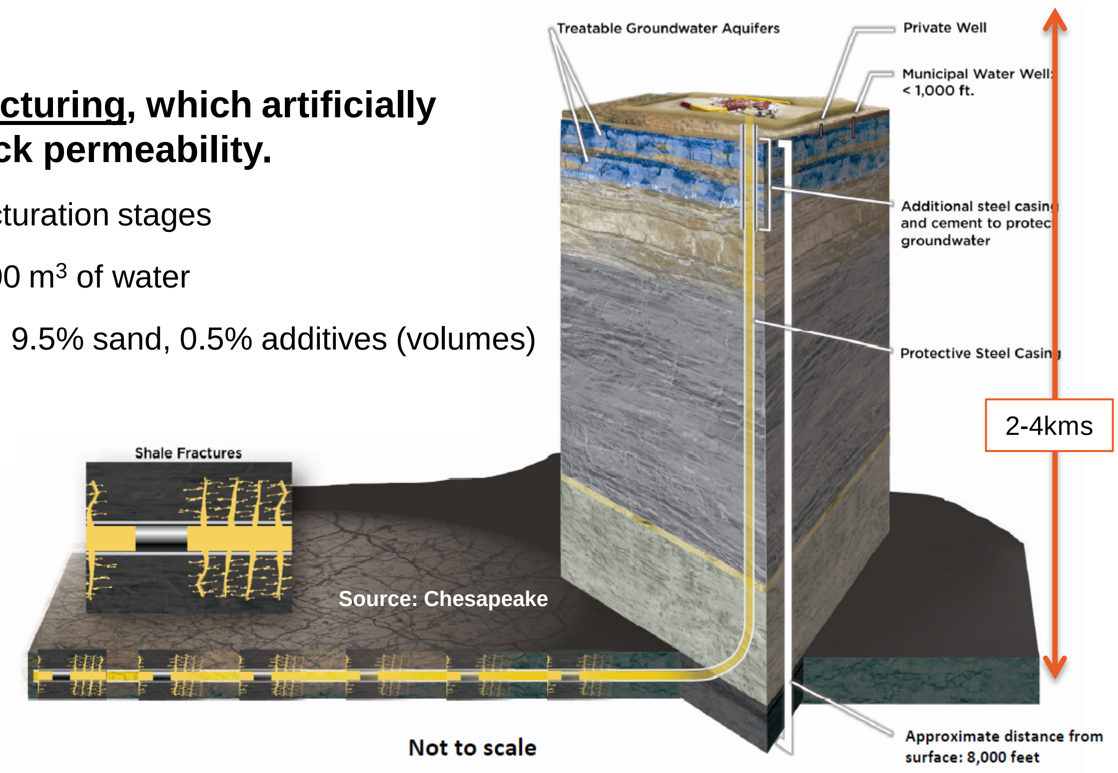
Rock characteristics require the usage of appropriate techniques, to ensure an acceptable level of well productivity.

PRODUCTION TECHNIQUES

- **<u>Horizontal drilling</u>, which increases the productive section of each well**
  - o Horizontal drain length = 1,500 to 2,000m

These techniques are known to the industry and also used for conventional hydrocarbon production

- **<u>Hydraulic fracturing</u>, which artificially increases rock permeability.**
  - o 5 to 10 fracturation stages
  - o 10 to 20,000 m^3 of water
  - o 90% water, 9.5% sand, 0.5% additives (volumes)

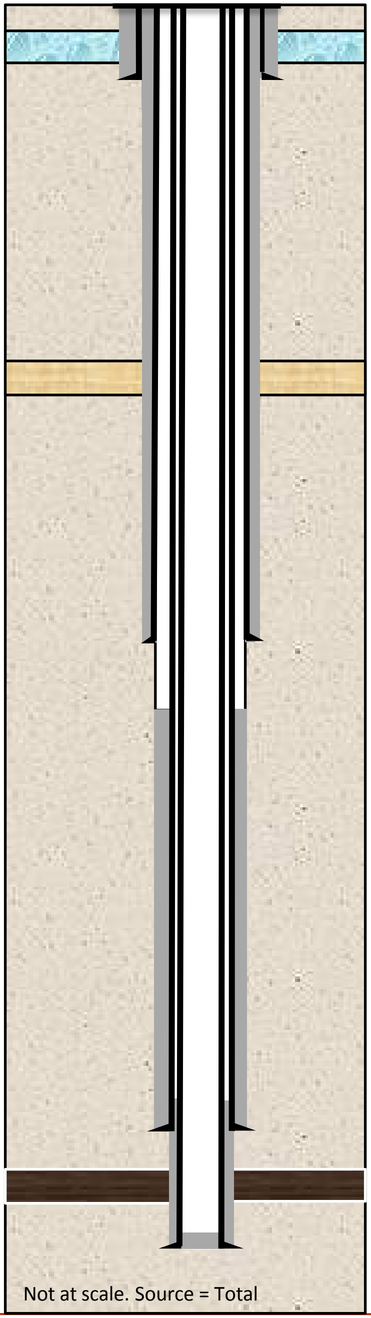


- **The amount of gas retrieved from each well remains low**
  - o This implies a large number of wells to reach a significant level of production

WELL ARCHITECTURE – A REMINDER

Shale gas wells are governed by the same principles as other types of wells. (conventional O&G, water, geothermal energy)

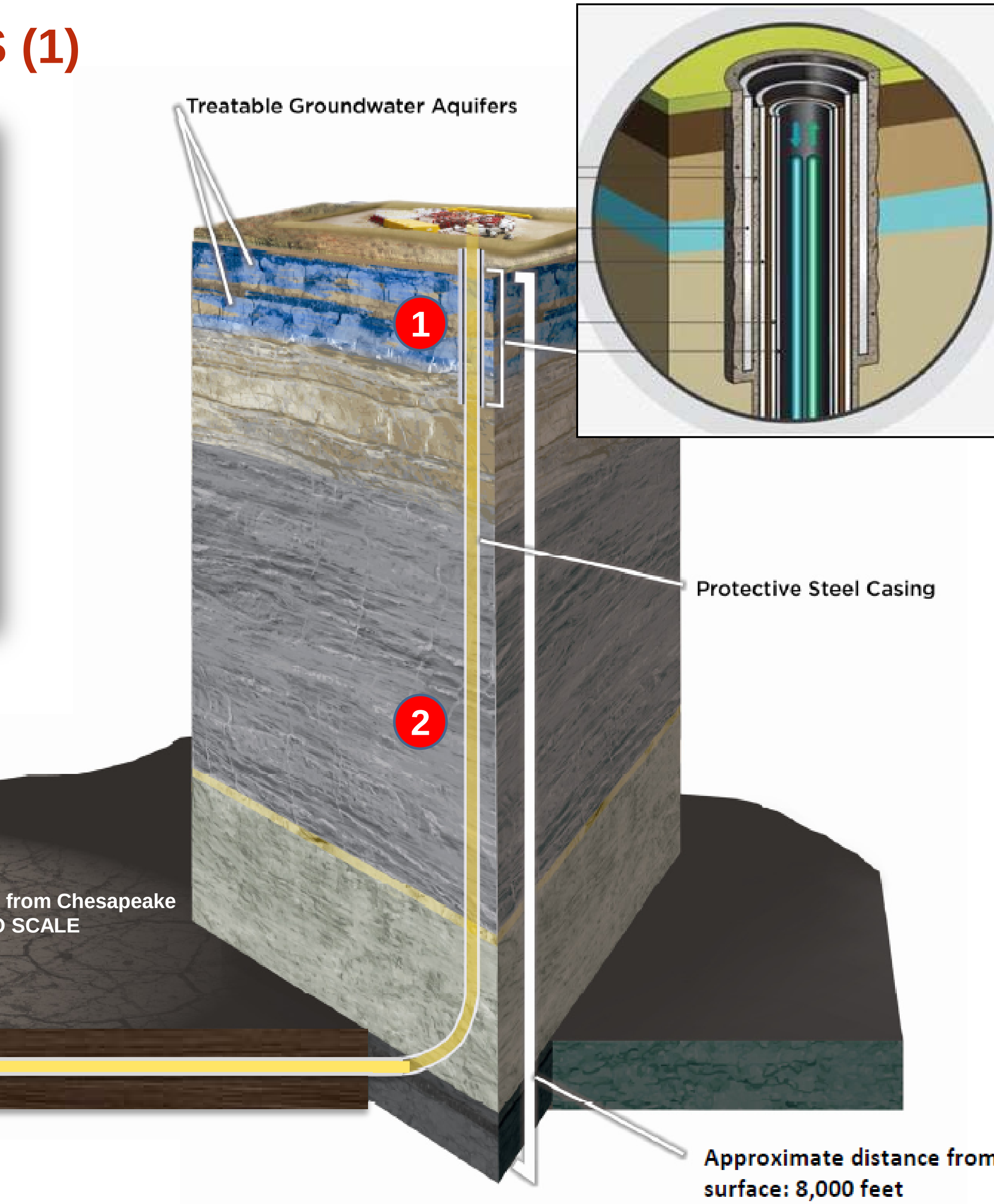
- **Well drilling operations are completed through a succession of phases.**
  - A drilling fluid is always present within the borehole.
  - A drilling phase is followed by running-in with a casing and its cementation.
  - Quality control for casing and cement integrity is compulsory.
- **Well design is aimed at isolation from the surrounding geological formations**
  - Pressure barrier (drilling fluid, mudcake)
  - Mechanical barrier (casing, cement)
- **Surface phases are designed to protect ground waters.**
  - Water based drilling fluids
  - One to two fully cemented casing strings



Drilling a well is a state-regulated process, following industry best practices and company internal procedures, using fit-for-purpose materials

SEQUENCE OF OPERATIONS (1)

1. Drilling, casing & cementing
2. Drilling, casing & cementing
3. Drilling, casing & cementing



Source: modified from Chesapeake
NOT TO SCALE

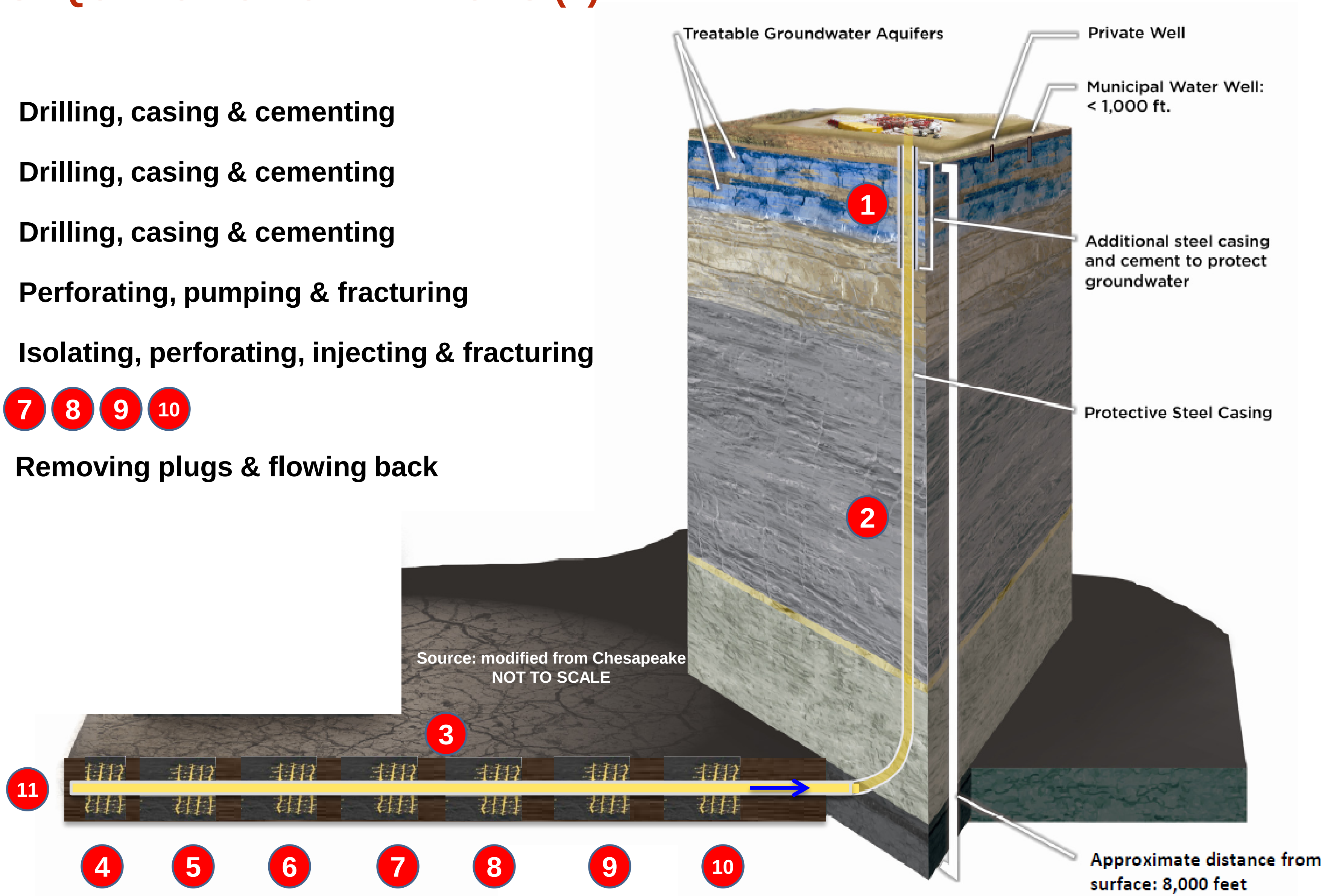
HYDRAULIC FRACTURING LAYOUT

SEQUENCE OF OPERATIONS (2)

1. Drilling, casing & cementing
2. Drilling, casing & cementing
3. Drilling, casing & cementing
4. Perforating, pumping & fracturing
5. Isolating, perforating, injecting & fracturing

6 7 8 9 10

11. Removing plugs & flowing back



Source: modified from Chesapeake
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FRACTURING FLUIDS

- **Slick water vs gel**

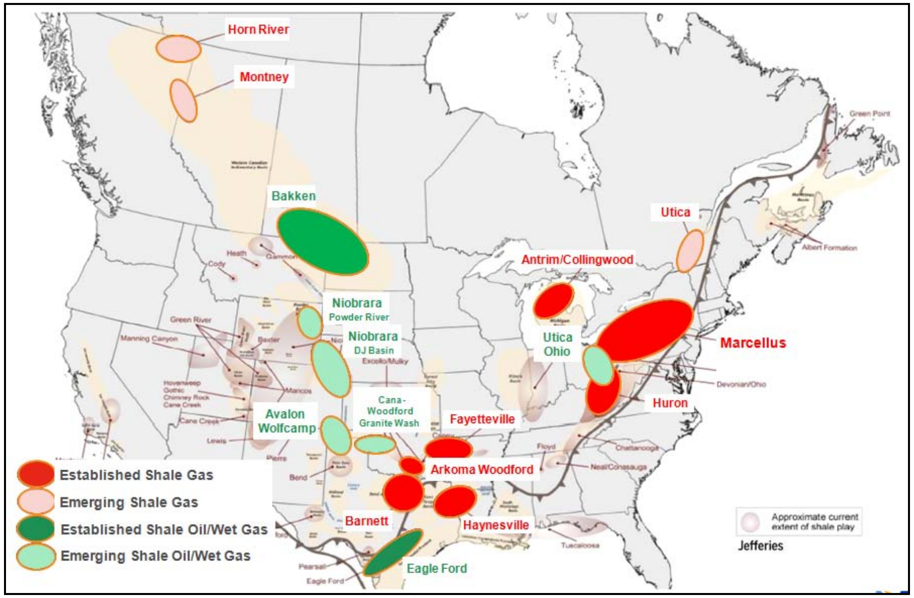
- **Additives role**
  - o Reduce frictions
  - o Improve proppant carrying capacity (gel)
  - o Allow water removal while leaving proppant downhole after frac (gel breaker)
  - o Remove bacteria
  - o Prevent corrosion and scale deposits
  - o Inhibit shale if needed

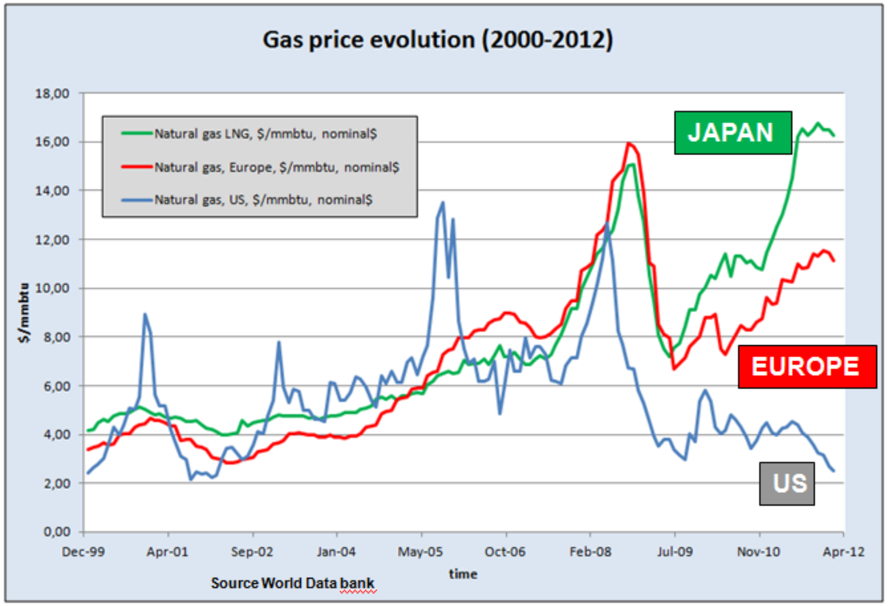
- **Way forward**
  - o Reduce required product quantities
  - o Substitution by alternative techniques (eg UV)
  - o Shift toward the use of low or non-toxic products (food industry), and biodegradable products
  - o Transparency: www.fracfocus.org

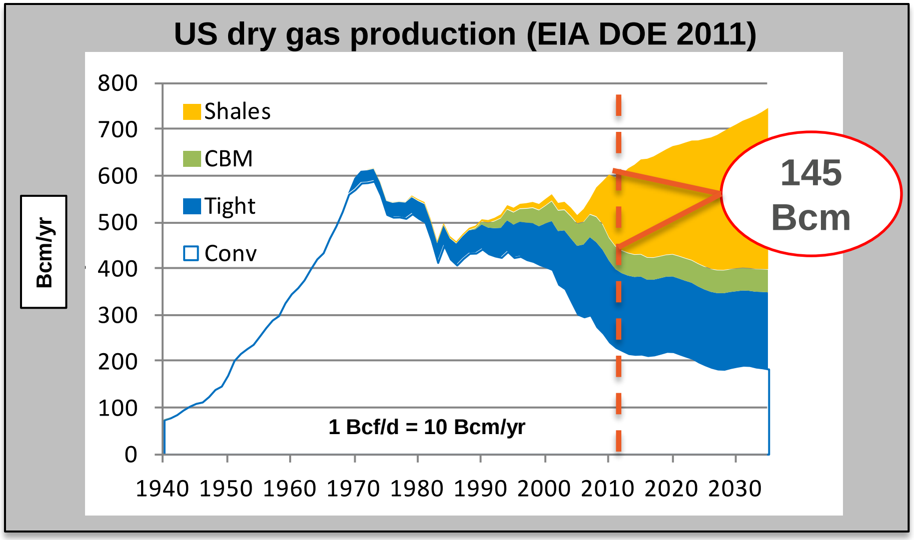
Concentration	Unit	Component in System	Purpose	MSDS
917	Liter	Water		
81	Liter	22% Liquid KCl		KCl
0.6 to 0.84	Kg	CleanWG1	Friction reducer	FDP-S951-09
0.12 to 0.36	Kg	CleanBreakE	Breaker	FDP-S981-10
1	Liter	CleanSurf	Non-emulsifying Surfactant	FDP-S962-09

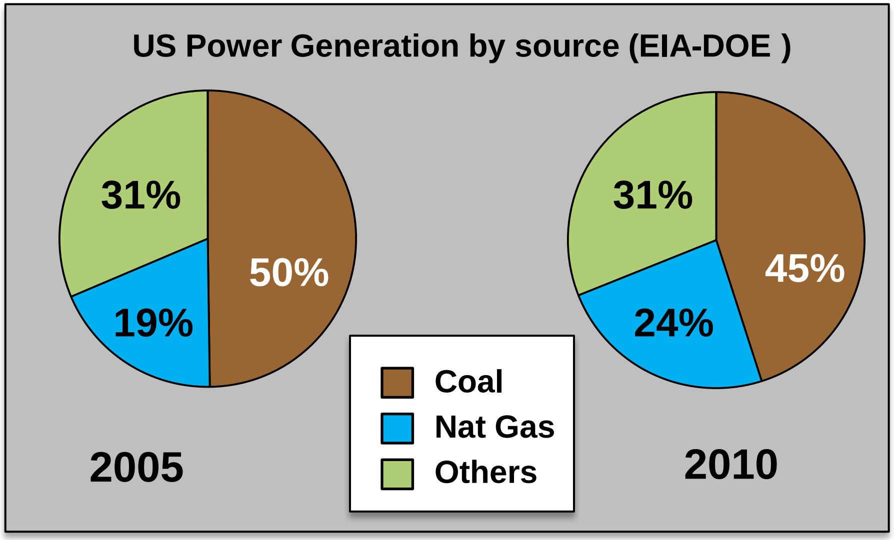
The exact fluid composition depends on reservoir properties and well conditions

SITUATION IN THE US









L'exploitation du gaz de schiste serait aussi nocive pour le climat que le charbon

Le Monde

GAZ DE SCHISTE

LA TERRE TREMBLE PRÈS DES PUITS

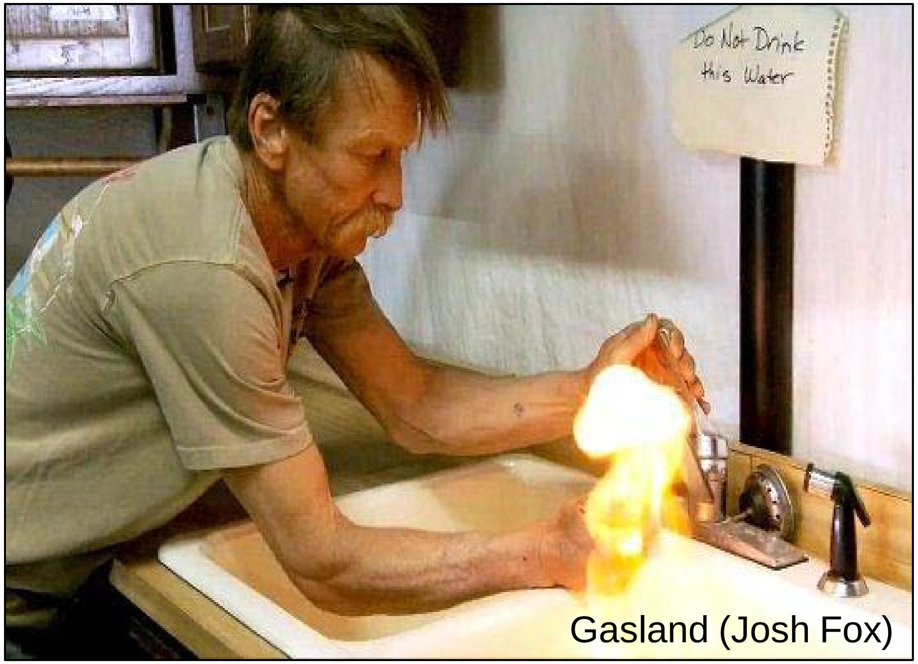
SCIENCE & VIE

Gaz de schiste : un pompage radioactif ?

l'Humanité

Un eldorado empoisonné

Le Monde



Gasland (Josh Fox)

L'exploitation du gaz de schiste à l'origine de « miniséismes » dans l'Ohio

Le Monde

CHALLENGES ASSOCIATED TO SHALE GAS PRODUCTION

Water

Protection of aquifers during drilling, fracturing and production

Minimize water usage

Stakeholders

Involvement in project preparation

Minimize impact of operations

Share benefits

Ground

Minimize land use

Management of industrial activities

Climate

Minimize Green House Gas emissions

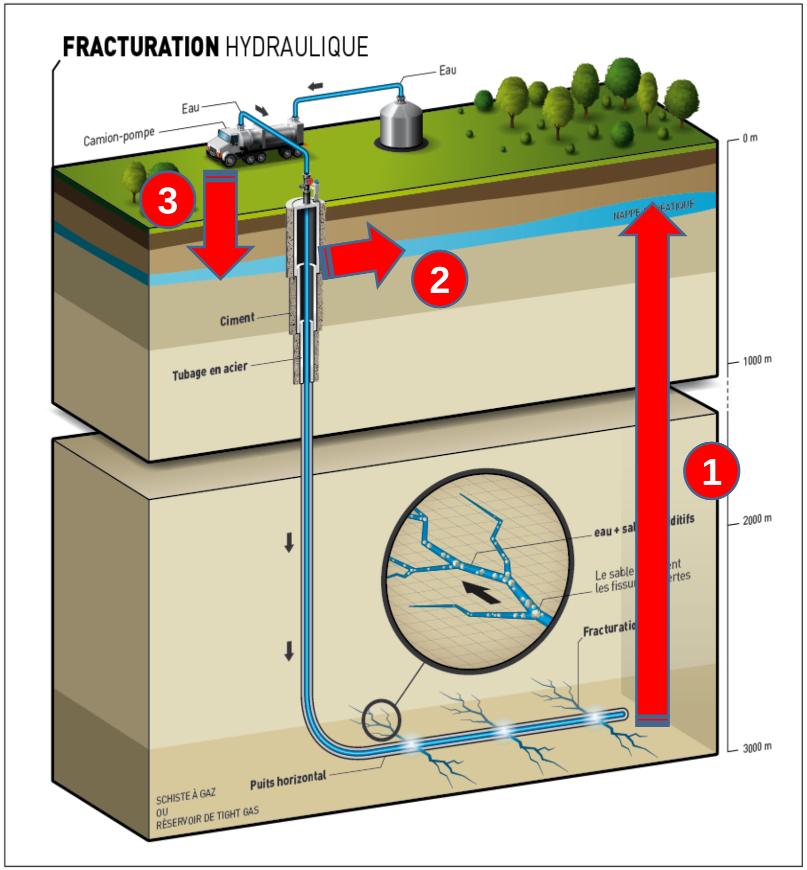
WATER MANAGEMENT

- **Origin**
  - Fresh water, brackish water, sea water
  - Surface water / ground water / recycled water
- **Quantity**
  - Drillling: 300 to 1,500 m^3
  - Fracturation: 5,000 m^3 to 20,000 m^3
  - Flow-back : 25 to 50% of injected volume
- **Transportation & storage**
  - Pipeline versus trucking

Water management is known to the O&G industry

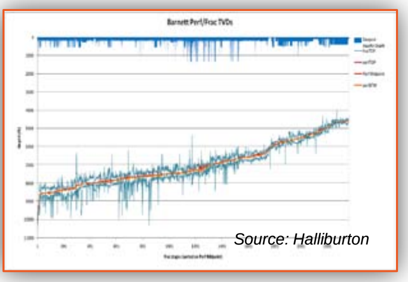
- **Treatment**
  - Technical solutions are available (large amount of produced water from conventional fields – up to 99%)
  - Selection to be made according to produced water characteristics
  - Adapt to local context: e.g. mobile versus centralized units
- **Recycling**
  - Operational
  - Water specs have been considerably lowered (e.g. TDS)
- **Disposal**
  - After treatment
  - Controlled by local regulations

AQUIFER CONTAMINATION : RISK PERCEPTION



1 Direct contamination due to hydraulic fracturing.

Risk considered as extremely unlikely given safe distances from aquifers are respected



2 Contamination due to well integrity issues.

Risk known to the O&G industry (and others), requires respect of regulation and good industry practices

3 Contamination related to spill or containment failure.

Risk known to the O&G industry and more widely to a large number of industries

FRACTURE HEIGHT GROWTH & AQUIFER POSITION

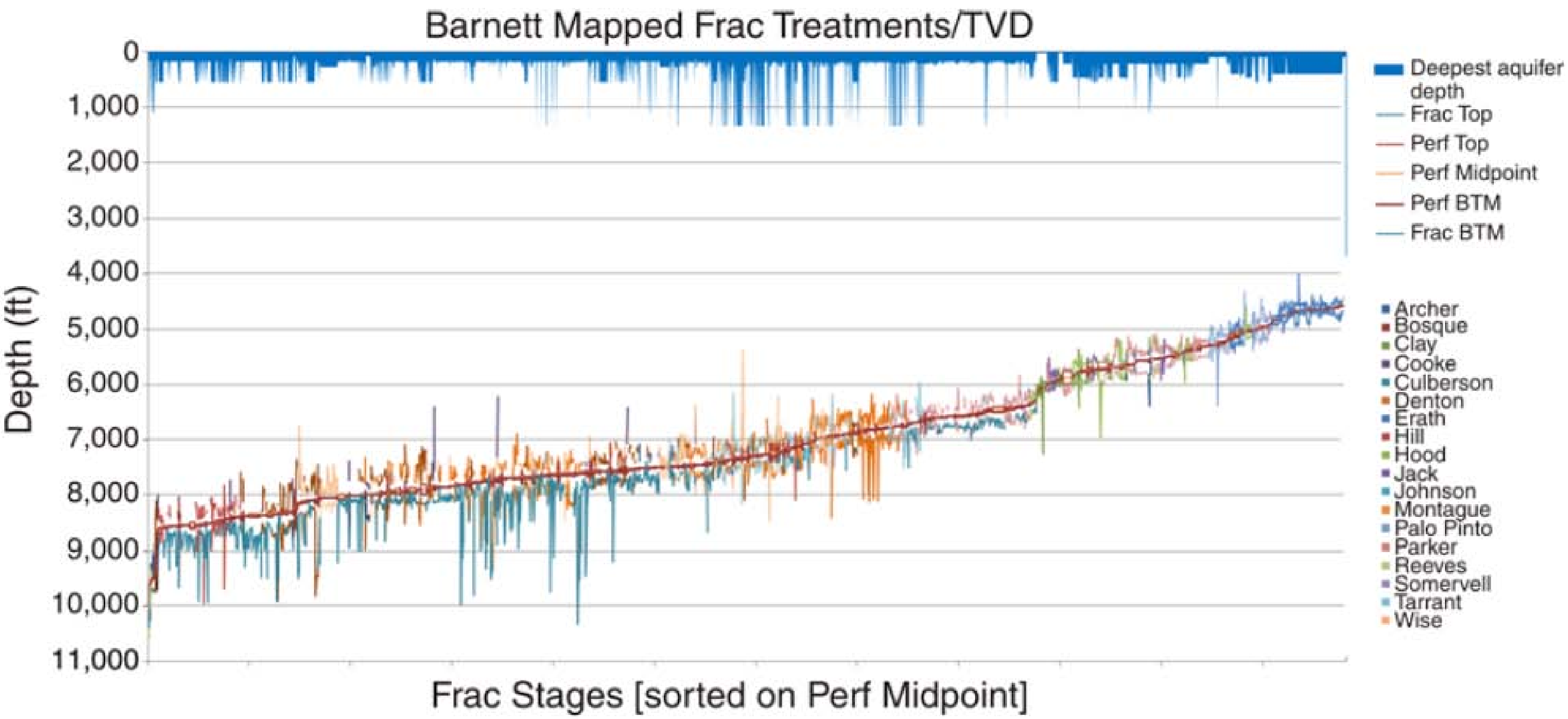


Fig. 2—Barnett shale measured fracture heights sorted by depth and compared to aquifers.

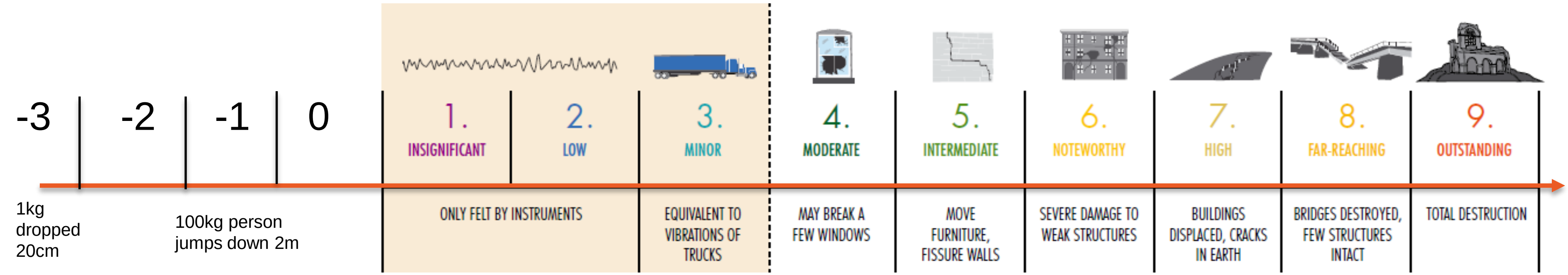
SPE 145949

Hydraulic Fracture-Height Growth: Real Data

Kevin Fisher and Norm Warpinski, SPE, Pinnacle—A Halliburton Service

SEISMICITY

The Richter Magnitude Scale



- Hydraulic fracturing treatments create extremely low levels of seismic activity typically around -1.5 on the Richter scale

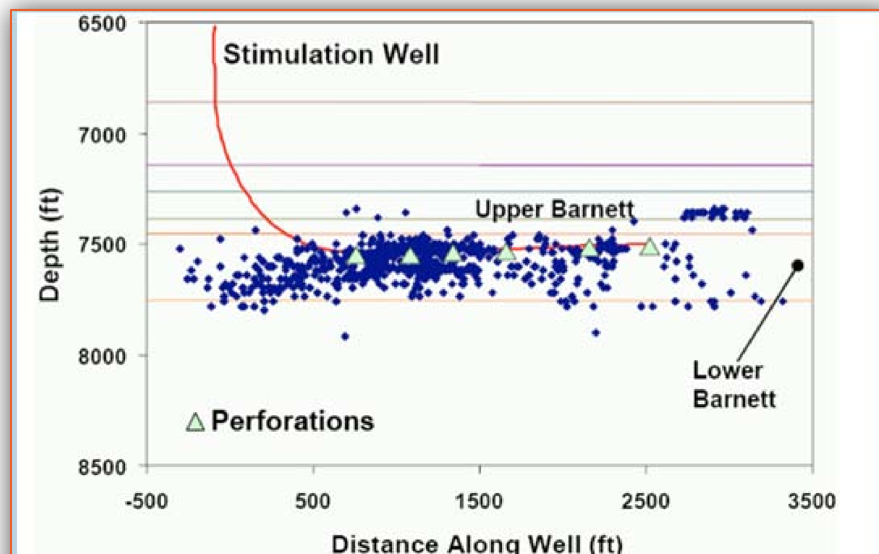


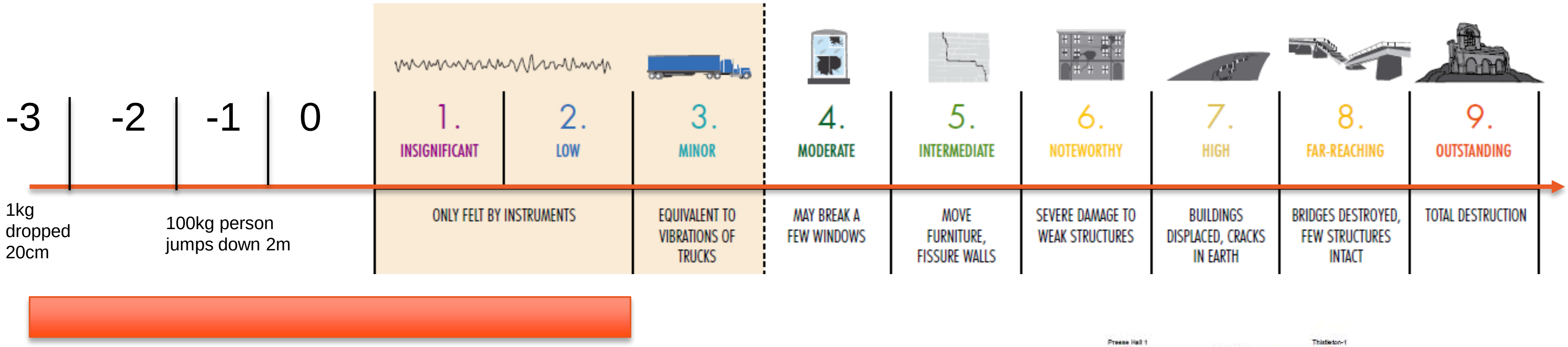
Figure 3. Cross section through a stimulation well showing six different stages of hydrofracture stimulation and the associated seismicity (magnitude -1.0 to -2.5) during the entire hydrofracture (less than 24 hours) Warpinski et al 2005.

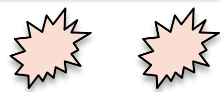
Note: Richter scale is logarithmic, e.g. 5 is 10x as much ground motion and 32x more energy released than 4

There are millions of tremors worldwide every year of which ~ 100,000 can be felt as earthquakes (3 or more on the Richter scale)

SEISMICITY

The Richter Magnitude Scale





- In exceptional cases when activating existing fault, (e.g. Blackpool at 2.3) hydraulic fracturing can induce higher seismicity (truck vibration equivalent)

Note: Richter scale is logarithmic, e.g. 5 is 10x as much ground motion and 32x more energy released than 4

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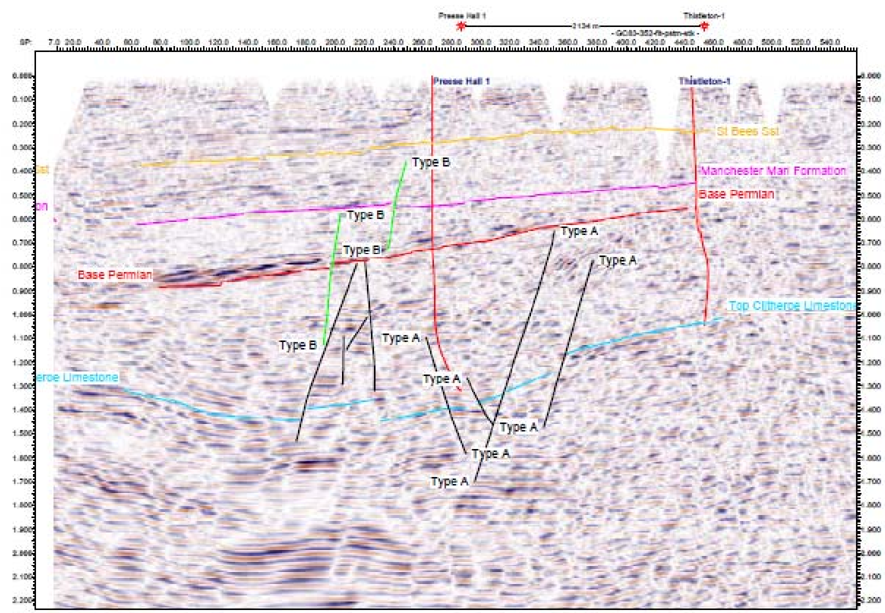
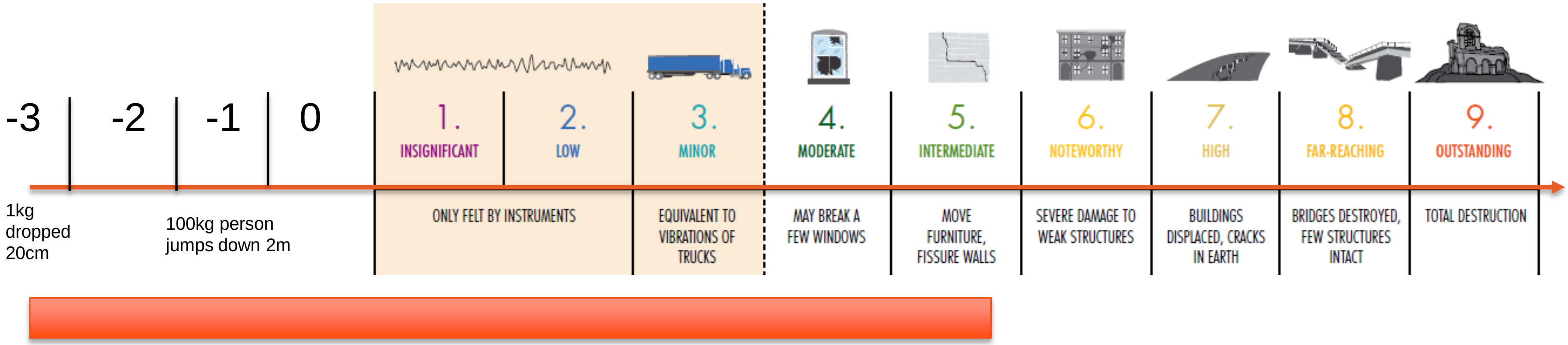


Figure 8: Reprocessed seismic section showing the two fault types, A and B in the proximity of Preese Hall-1 and Thistleton-1. The seismicity was caused by a type A fault that is contained in the Carboniferous.

SEISMICITY

The Richter Magnitude Scale

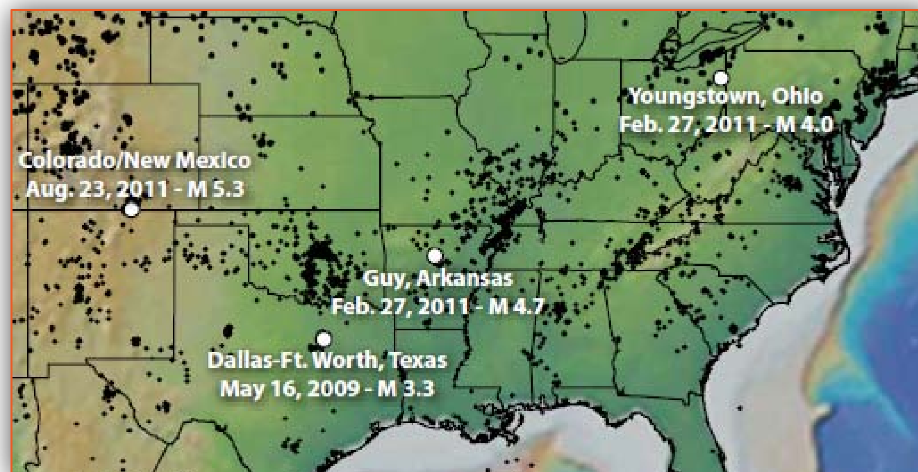


A number of the small-to-moderate earthquakes appear to be associated with the disposal of wastewater, at least in part related to natural gas production.

They are not triggered by hydraulic fracturing but by waste water injection;

Approximately 140,000 wastewater disposal wells have been operated in the U.S. for many decades.

Such injection operations are highly restricted, when not forbidden, in European countries

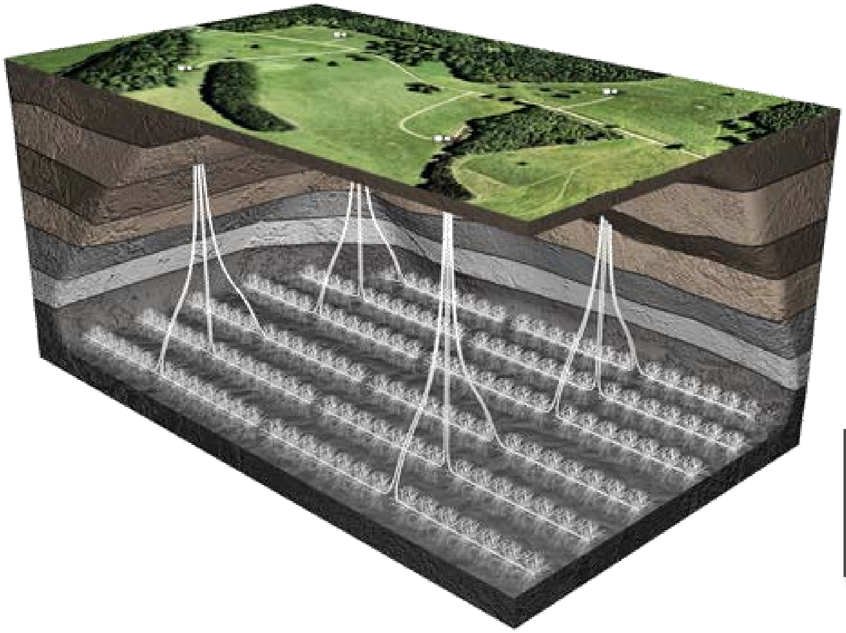


SURFACE FOOTPRINT

1. Drilling & fracturing
A few weeks/well - largest footprint

2. Production
10-25 years – Low impact

3. After production
Site is restored



- **Solutions to reduce surface impact do exist:**
  - o “cluster” based developments
- **Integration within the local industrial, urban or agricultural context is critical**
  - o Look for upstream and downstream synergies

Solutions to reduce the industrial impact have to be adapted to the local context


200 m
1000 pieds
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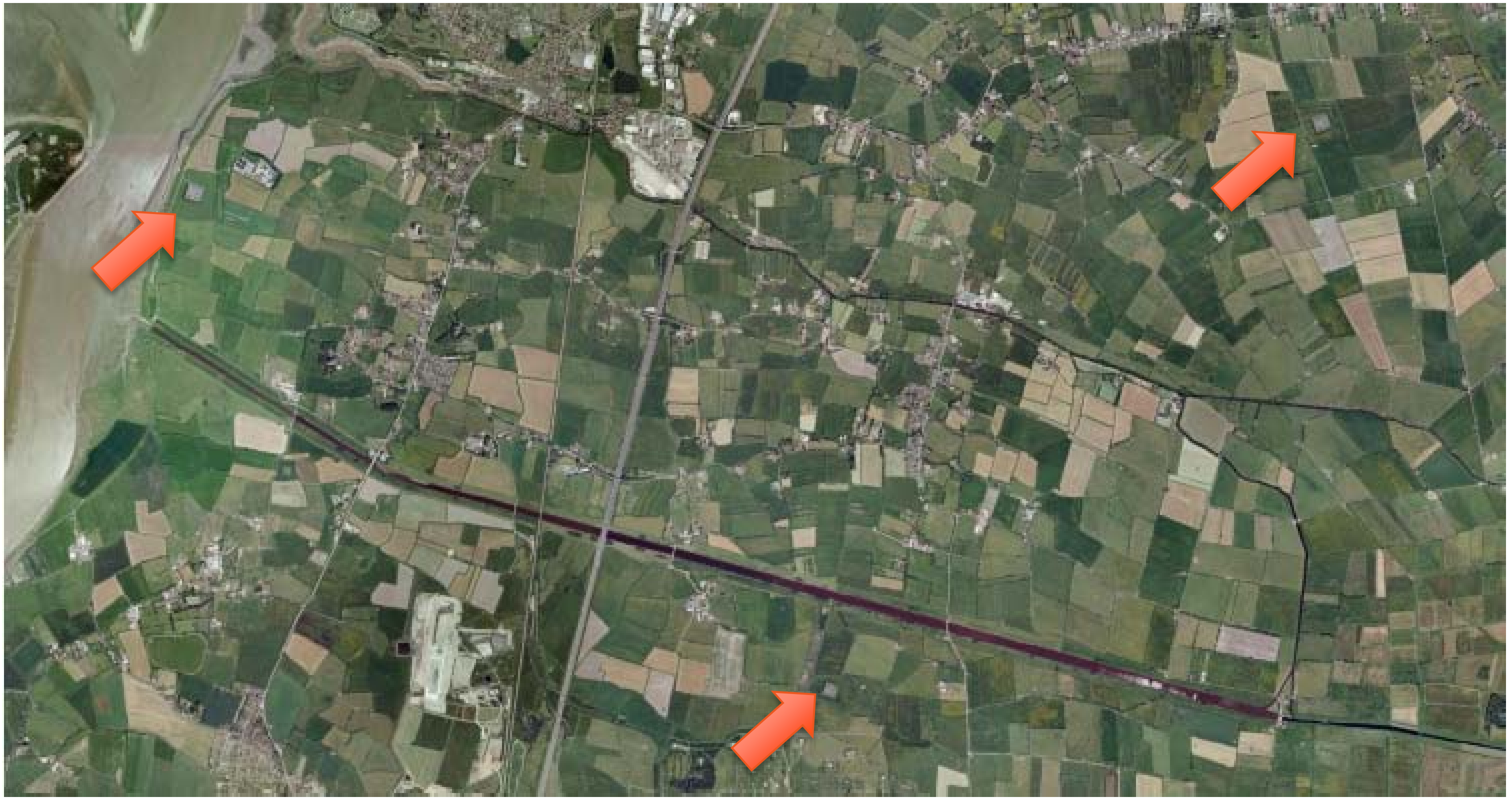
TOTAL

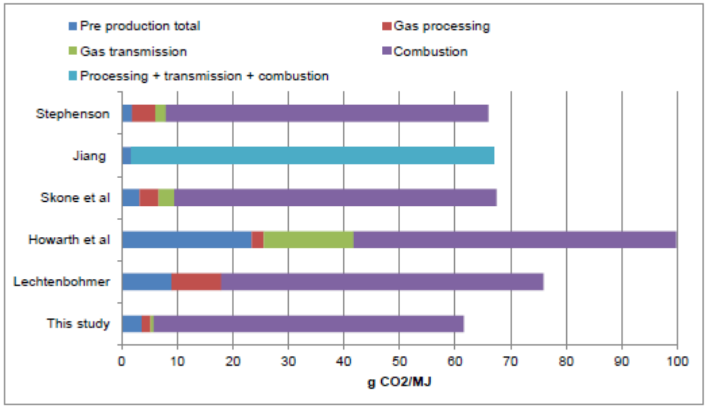


Source = Cuadrilla

GHG IMPACT OF SHALE GAS PRODUCTION

- **Combustion is responsible for most GHG emissions in shale gas life cycle**
- **When used to produce electricity, all sources of natural gas have lower GHG emissions than coal**
  Source: e.g. AEA report for the European Commission DG CLIMA (2012)

Figure 10: Comparison of lifecycle GHG emissions for shale gas from this study and others



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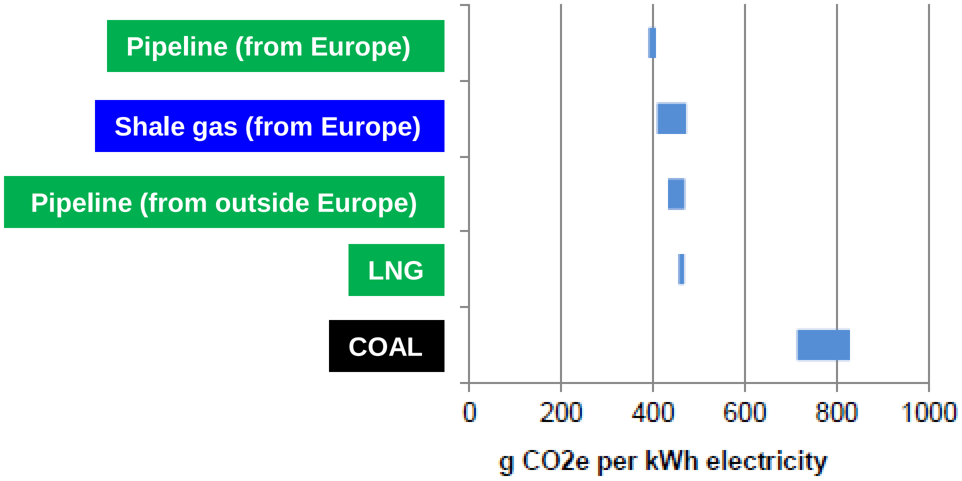


- **Shale gas and conventional gas GHG emissions are comparable**
  - GHG emissions from Barnett shale (TX) have a similar GHG footprint as US conventional natural gas production (*NETL comprehensive study 2010)*
  - Marcellus shale gas have 3% more emissions than average conventional gas *(Carnegie Mellon University (Jiang et al.) 2011)*

Climate impact will depend on the usage made of shale gas.

Additional consumption of fossil fuel / replacement of gas import / coal substitution

STAKEHOLDER RELATIONS IN EUROPE

- **A challenging context:**
  - Rejection of fossil fuels
  - Poor image of the industry, of the O&G industry in particular(big oil)
  - Adversity to risk and to industrial risk in particular (GMO, nanotechnology...)
  - Growing expectations from the civil society, in particular in terms of access to information
  - Lack of trust in the industry, in the political bodies and even in technology and science in general
  - Modern communication tools give access to a mass of information, not verified, which allows anybody to think he/she is an expert on complex subjects.
  - Lack of trusted independent reference

- **Complicated by:**
  - Onshore projects – in people's backyard
  - A legal framework which does not provide many incentives at the local level (mining rights, tax structure)

Strong expectations in term of transparency and access to information

International Energy Agency 2012

1- Measure, disclose & engage

2- Watch where you drill

3- Isolate well and prevent leaks

4- Treat water responsibly

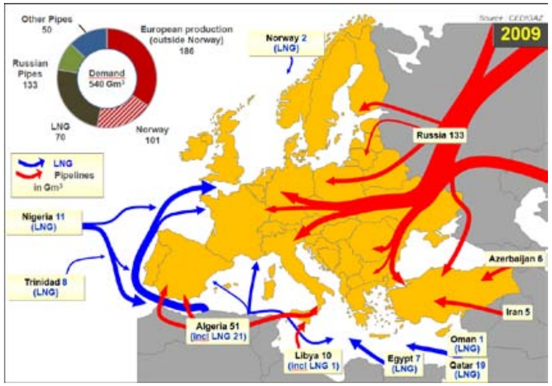
5- Eliminate venting, minimize flaring & other emissions

6- Be ready to think big

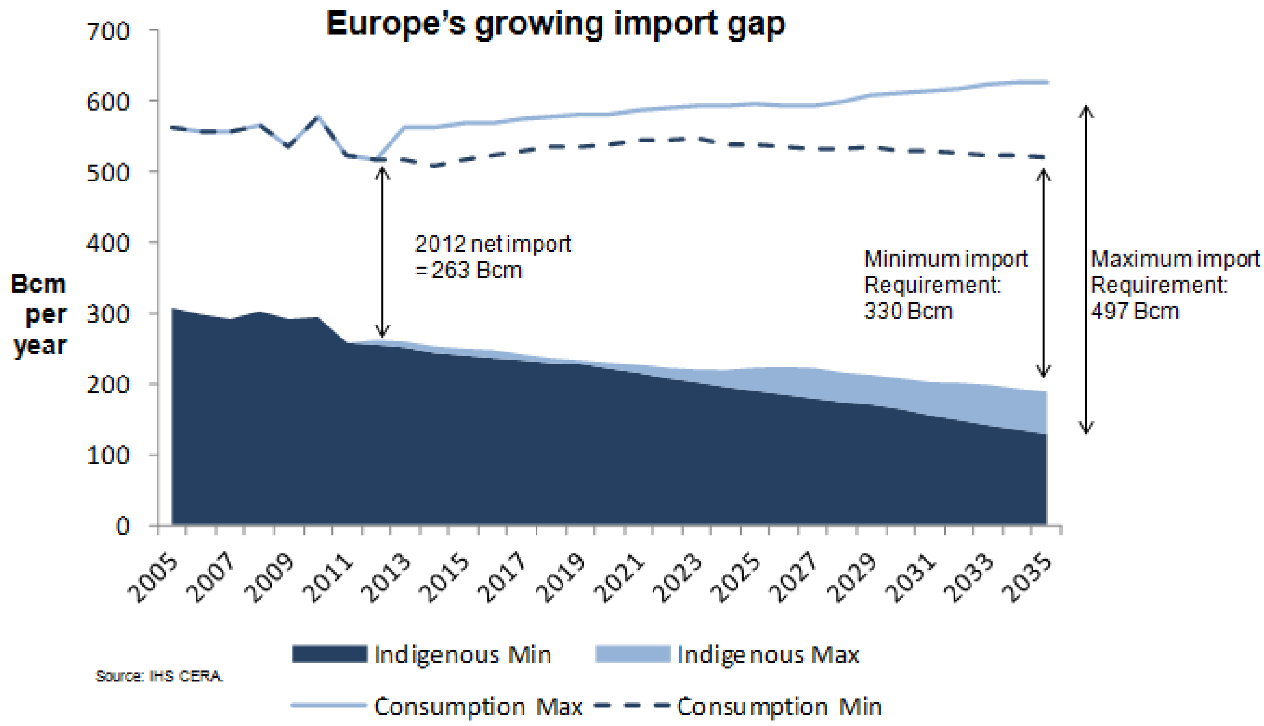
7- Ensure a consistently high level of environmental performance

EUROPE NEEDS AFFORDABLE GAS

- Decreasing domestic production
- Shift away from nuclear power
- Objectives of GHG emissions limitation favoring gas over coal
- Political will to limit dependency on imports
- Industry competitiveness



Source: CEDIGAZ (2009)



EUROPE - SEDIMENTARY BASINS WITH SHALE GAS POTENTIAL

- **Exploration for shale gas started in Europe in 2007/2008 and has slowly progressed**
- **Little is known about its ultimate shale gas potential**
- **Various studies suggest significant resources …. <u>but this is yet to be proven</u>**

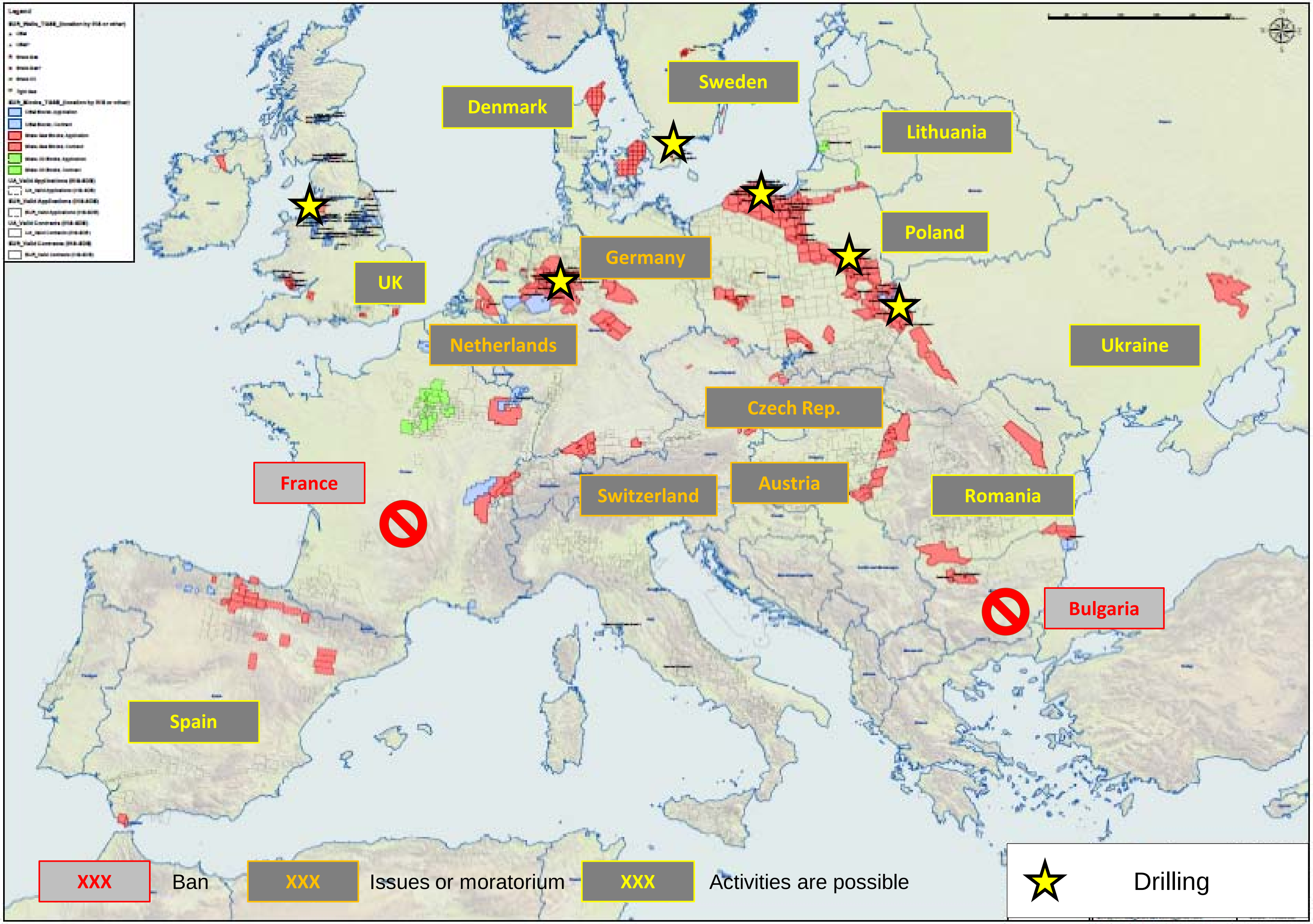
EUROPE	Proved conv. gas resources (Tcf) EIA 2011	Technically recoverable resources (Tcf) EIA 2011
France	0,2	180
Germany	6,2	8
Netherlands	49	17
Norway	72	83
UK	9	20
Denmark	2,1	23
Sweden		41
Poland	5,8	187 (rev PGI 12-27)
Turkey	0,2	15
Ukraine	39	42
Lithuania		4
Others	2,7	19

French consumption = 1.8 Tcf/yr
Lacq = 8.5 tcf cumulated production

Source: IEA 2012

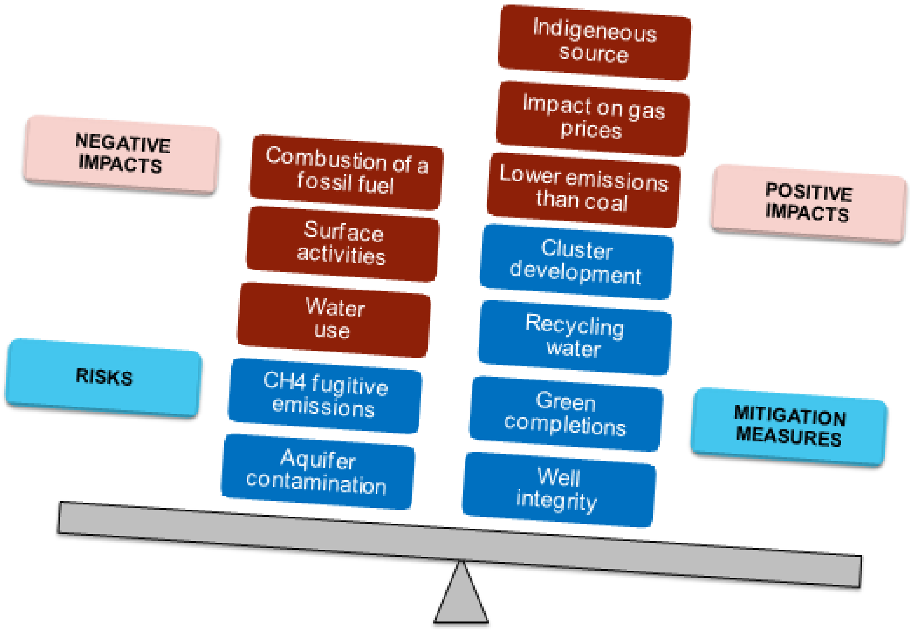
Resources figures are as large as uncertain at this stage

EUROPE - SHALE GAS ACTIVITY



IN A NUTSHELL

- **Shale gas exploration is still in its infancy in Europe;**
- **There are associated challenges;**
  - which are well-identified
  - which can (technically) be addressed in a safe way
  - And addressed through adequate regulations and industry practices
- **Societal acceptability is key**
- **Shale gas will only be developed if industry, governments and the civil society are convinced it is worthwhile.**



- **If developed, it will be with a different business model compared to the U.S.:**
  - Much more technology-based, minimizing wells, water use, land take;
  - Adapted regulations, expansion of services sector, compensations for local communities

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