

Cracking down on fracking: shale gas & HSE risks

Shale gas revolution

The past few years have seen a revolution in natural gas supply driven by a boom in the production of unconventional gas resources, such as shale gas. US gas prices have decoupled from oil and have fallen by more than 60% since the peak in 2008. With up to 2,500tcf in recoverable resources, shale gas is expected to account for nearly two-thirds of US gas production by 2035. Globally, recoverable shale gas reserves are equivalent to over 60 years of current annual consumption.

But growing HSE concerns over fracking

The shale gas boom has largely been premised largely on advances in horizontal drilling and the practice of "fracking", which involves pumping a mix of water, chemicals and proppants into wells to unlock the gas. Fracking has raised a number of health, safety and environmental (HSE) concerns, with stakeholders pointing to potential risks associated with emotive issues like freshwater use and injected water and wastewater treatment, as well as full life-cycle greenhouse gas emissions. Other potential HSE concerns are biodiversity, clean-up, faults and fissures, and pipelines.

Greater scrutiny & regulation lies ahead

Companies and investors cannot afford to ignore these "fractivists", as regulators are following stakeholders in moving towards greater scrutiny of potential HSE risks. Fracking is the subject of moratoriums and bans in a number of US cities and states, as well as in France. It is currently under investigation by the US Environmental Protection Agency (EPA), the Securities and Exchange Commission (SEC), and the European Commission. We expect this to result in much more stringent HSE regulation and disclosure requirements.

Cost impact could make or break some shale plays

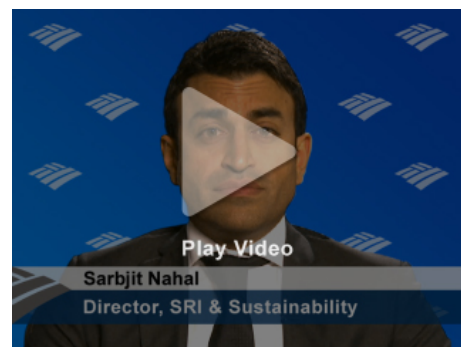
It is too early to estimate the potential cost burden of regulation, but producers can expect additional costs arising from red tape, increased drilling costs, delays in production, greener practices, greater disclosure, and potential litigation and regulatory risks associated with fracking. This could be margin make-or-break for higher-cost shale fields and may result in tightened shale gas supply.

Bearish on shale or bullish on shale regulation? Go green

Assuming shale gas is hit by stricter regulation, we believe that investors might seek three types of investment exposure: 1) Water and wastewater companies to treat recovered fracking fluid; 2) Oil services companies that are developing green(er) fracking chemicals to reduce water-related risks; and 3) Renewable energy and utility companies on the back of higher gas prices.

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Table 1: BofAML Green Fracking Stocklist

Fracking chemicals	Ticker
BAKER HUGHES	BHI US
BASF	BAS GR
HALLIBURTON	HAL US
SCHLUMBERGER	SLB US
Wastewater treatment	Ticker
CAMERON	CAM US
CHESAPEAKE ENERGY	CHK US
GENERAL ELECTRIC	GE US
LINDE	LIN GR
NALCO HOLDING	NLC US
RANGE RESOURCES	RRC US
SIEMENS	SIE GR
VEOLIA	VIE FP
Renewables & Utilities	Ticker
EDP RENOVAVEIS	EDPR PL
FIRST SOLAR	FSLR US
GDF SUEZ	GSZ FP
IBERDROLA	IBE SM
INTERNAT'L POWER	IPR LN
NEXTERA ENERGY	NEE US
SUNPOWER CORP.	SPWR US
VESTAS	VWS DC

Source: BofA Merrill Lynch Global Research

Shale gas & HSE risks in brief

The past few years have seen a revolution in natural gas supply driven by a boom in the production of shale gas, which could see it account for up to two-thirds of US gas production by 2035 (Source: IEA). This boom has partly been driven by the practice of hydraulic fracturing, or "fracking", which raises a number of potential HSE concerns including water use, injected water and wastewater treatment, as well as full life-cycle greenhouse gas emissions. These concerns are already on stakeholders' agendas and are now under investigation by the US EPA and SEC and European Commission, among others.

Greater scrutiny, regulation & costs

We believe that the combination of stakeholder and regulatory scrutiny will result in much more stringent HSE regulation and disclosure requirements for the shale gas industry. This will mean additional costs arising from red tape, increased drilling costs, delays in production, greener practices, greater disclosure, and potential litigation and regulatory risks associated with fracking. This could be margin make-or-break for higher-cost shale fields and may result in tightened shale gas supply.

Look for investment opportunities

Assuming that shale gas is hit by stricter regulation, we believe that investors might seek three types of investment exposure:

1. **Water and wastewater companies** to treat recovered fracking fluid;
2. **Green(er) fracking chemicals** providers to reduce water-related risks; and
3. **Renewable energy and utility companies** on the back of higher gas prices.

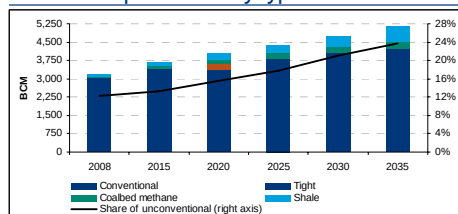
The shale gas revolution

The past few years have seen a revolution in natural gas supplies driven by a boom in the production of unconventional gas resources such as shale gas, tight gas and coal bed methane. These developments come as countries around the world are looking to unconventional gas to develop secure and sustainable energy supply and to reduce GHG emissions – with the IEA projecting that global gas demand will rise by 60% by 2035.

Unconventional gas boom, 11% global production by 2035

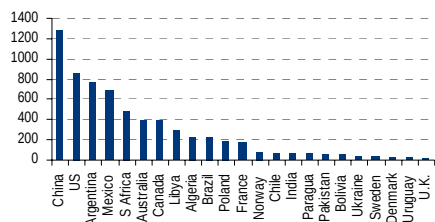
According to the IEA's World Energy Outlook 2011, most of the increase in unconventional gas production will come from shale gas and CBM. The IEA predicts that the share of shale gas in global gas production will reach 11% in 2035. In North America, unconventional gas, mostly shale gas, could increase from accounting for less than half of overall gas production in 2008 to nearly two-thirds by 2035.

Chart 1: NG production by type to 2035*



Source: IEA. * Under the GAS scenario which incorporates a combination of new assumptions that underpin a more positive future outlook for gas.

Chart 2: Technically recoverable shale Gas (tcf)



Source: EIA 2011

To date, there have been few documented cases of groundwater contamination because of chemicals used in fracking

Exponential US shale gas growth, others looking to follow

The US has already seen exponential growth in shale gas since large-scale drilling and production efforts began with the Barnett Shale in 2006. Between 2007 and 2010, US shale gas production tripled on the back of technological advances and lower production costs – and its percentage contribution to domestic natural gas consumption increased from about 5% to over 20%. China, Latin / South America, Australia, Canada, North Africa and Poland, among others, are all similarly looking to develop their shale gas resources.

Fracking & HSE risks

The combination of horizontal drilling and hydraulic fracturing (“fracking”) has granted access to large volumes of shale gas that were previously uneconomical to produce. Fracking involves pumping a mix of water, chemicals and proppants into the well to unlock the hydrocarbons trapped in shale formations by opening cracks (fractures) in the rock and allowing natural gas (NG) to flow from the shale into the well. Fracking has raised a number of HSE (health, safety and environmental) concerns including:

- **Freshwater use:** fracking involves large-volume water withdrawals from ground and surface water, using an average of 2-5mn gallons of water per well, and in some cases up to 13mn. With companies drilling up to 16 wells per pad, this amounts to 32-64mn gallons of water per pad. Shale gas is projected to grow rapidly globally, meaning freshwater withdrawals, water scarcity and non-potable water are all issues for shale gas plays.
- **Injected water & wastewater:** chemicals are added to the water to facilitate the underground fracking process. Although they constitute only 0.5% to 2% of the fracking fluid, the chemicals are potentially harmful to human health. This is a concern given that only 50-70% of the volume of fracking fluid is recovered, raising the potential risk of contamination of: (1) groundwater (although the injected water depth is below the groundwater base); and/or (2) surface aquifers. Moreover, wastewater treatment of fracking water is becoming an issue, as municipalities have limited capacity to treat the recovered, contaminated water.
- **GHG emissions:** while some have advocated the use of shale gas on the basis that it releases fewer GHGs than other fossil fuels, there is a growing body of evidence suggesting that shale gas could emit more full GHGs – “well to burner” – than conventional NG, and potentially even coal or oil. The controversy centres on potent methane emissions over the full lifecycle footprint of shale gas.

Other potential HSE issues include blow-out safety concerns, biodiversity, the lack of capacity for clean-up, the possibility of faults, fissures and earthquakes and an emerging pipeline debate.

Regulators cracking down on fracking

The development of the shale gas sector has largely been one step ahead of regulations and oversight – with a patchy network of state-by-state or country-by-country requirements, restrictions, or frequent lack thereof across the globe. This appears to be changing, with a number of jurisdictions recently passing moratoriums or introducing more stringent restrictions on shale gas drilling and tracking. We believe this will continue and that regulators will try to find a middle ground between HSE concerns over fracking, energy security and job creation and economic development. The tenor of the global debate should be set by:

SEC is looking to ensure investors are told about the potential fracking risks that a company may face

- **US EPA investigation:** Congress has asked the EPA to study the safety of the hydraulic fracturing technology and the potential dangers to groundwater. Research should be completed by the end of 2012, and the EPA's Hydraulic Fracturing Report is expected to be completed in 2014 with the findings likely to go some way towards clarifying some of the HSE issues around shale oil for the US market.
- **US SEC investigation:** The SEC has recently stepped into the fray and is both seeking greater disclosure from companies on fracking risks and the chemicals used, and issuing subpoenas, indicating a more formal investigation is under way. While it is still early days, the effects could be significant, especially given that the potential risks associated with fracking impact almost all O&G development companies (with fracking also used for conventional wells).
- **EC favouring EU-wide rules:** Brussels intends to draft EU-wide rules on shale gas reserves, according to the Commission's Energy Commissioner, who has said that it is seeking environmental protection standards that enable member states to grant licences within a clear framework – which he feels are best achieved by European common standards. He has suggested that the Commission might put the proposals to member states as early as spring 2012. The European parliament is also looking to an Energy Quality Directive that could penalise or even ban shale gas.

Greater scrutiny, regulation & costs

The potential HSE risks associated with shale gas are, in our view, likely to lead to much stricter regulation on a 1-3Y time horizon. At the very least, we think that we will see much more in the way of regulation along the lines of recent decisions to require energy companies to disclose chemicals used in the fracking process. We also anticipate regulations covering the treatment of the fluids used to drill a well, tighter restrictions on where companies get water, stricter standards for the casing that lines a well hole and a greater government role in water monitoring.

Cost impact could make or break some shale plays

While it is too early to estimate the cost of such regulation, producers can expect additional costs arising from red tape, increased drilling costs, delays in production, greener practices, greater disclosure, and potential litigation and regulatory risks associated with fracking. We are seeing companies take note of this with protection clauses being included in shale gas purchases, allowing the acquiring company to walk away if new laws restrict fracking. Greater regulation could ultimately be margin make-or-break for higher-cost shale fields – and could result in tightened shale gas supply.

Companies need to adopt a prudent approach to shale gas

For shale gas to achieve a long-term licence to operate globally, industry must deal with the HSE impacts of E&P, comply with existing regulations, pro-actively anticipate new regulations and ensure stakeholder buy-in. We are seeing growing signs of this realisation, such as through stakeholder-friendly industry partnerships like FracFocus.

Still a long way to go

But they still have a long way to go to prove to stakeholders and regulators that they are: safeguarding the quality and quantity of regional surface and groundwater resources through sound wellbore construction practices; sourcing

fresh-water alternatives and recycling water for reuse as far as is practicably possible; measuring and disclosing water to reduce the environmental impact; supporting the development of fracturing fluid additives with the least environmental risk; and supporting the disclosure of fracturing fluid additives.

Chart 3: Shale gas success will mean balancing technology, economics and HSE concerns

	Optimal Drilling & Completions	Environmental Sustainability	Integrated Business Model
Unconventional Gas Challenges Internationally	- Optimal well placement - Improved drilling efficiency - Optimal stimulation design	- Optimal water management - Ensuring well integrity - Sustainable frac chemicals	- Operational flexibility - Integrated decision making - Stakeholder management
Challenging Economics			
Restricted Land Access			
Water Constraints			
Environmental Concerns			
Higher Prospectivity & Risk			

Solution is critical to challenge Solution is of little relevance to challenge

Source: SBC, BofA Merrill Lynch Global Research

Bearish on shale? Go green

While it is still early days, we anticipate that oil and gas companies will increasingly be forced to look for green(er) fracking solutions with nascent investment opportunities arising from both wastewater treatment and fracking chemicals. Should gas prices move higher on the back of tougher HSE standards for shale gas, then we would also become incrementally more positive on the renewable sector.

Wastewater treatment, a multi-billion-dollar market

The market for wastewater treatment for shale gas wells could be worth tens of billions of dollars over the coming years. Water-intensive fracking will generate billions of gallons of contaminated water that will need to be treated. This should create significant long-term opportunities for companies involved in wastewater treatment solutions such as bag filters, combination, chemical precipitation, distillation, electric coagulation, membrane filtration, desalination and mobile treatment units (MTUs). Given the estimated life of shale plays, this market could reach US\$2-4bn per year in the coming years.

Increased regulation could create a US\$100bn market for wastewater treatment over the next 30+ years

Table 2: Water & Wastewater treatment solutions providers

Ticker	Name	Country	MCap (USD Mn)	BofAML Ticker	BofAML Rating	Green shale gas exposure
Private	212 RESOURCES	United States	Not listed	NR	NR	Proprietary technologies that solve water management challenges from gas development and production. Offers a transportable plant, or pod, that uses thermal distillation and evaporation combined with polishing technologies such as sonic and advanced UV light which can process flow-back or produced water at well sites to create drinking-quality water. The patented system self-cleans while separating and recovering NG condensate, methanol and brine to produce distilled water that can be reused in drilling, for completions make-up, or for discharge into the natural environment.

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Table 2: Water & Wastewater treatment solutions providers

Ticker	Name	Country	MCap (USD Mn)	BofAML Ticker	BofAML Rating	Green shale gas exposure
ABHD US	ABTECH INDUSTRIES, INC	United States	20.80	NR	NR	Water treatment technologies & systems including EPA-approved storm water antimicrobial and new approach for oil and gas industry. Its products are based on polymer technologies capable of removing hydrocarbons, sediment and other foreign elements from still or flowing water.
AQE CN	AQUA-PURE VENTURES INC.	Canada	10.55	NR	NR	Provides integrated solutions for treatment and reuse of flowback and produced water. Developed a patented wastewater distillation process used in wastewater recycling. Clear Solutions system provides evaporation technology that can easily mix with other wastewater-treatment methods. It has cleaned up more than 500mn gallons (1.9 million m3) of water in the Barnett Shale and plans to use this expertise in the Marcellus Shale
Private	AquaTech Systems	United States	Not listed	NR	NR	Treatment offerings for flowback and produced water including the MoVap™, Mobile Evaporator, for onsite treatment at wellhead and Zero Liquid discharge (ZLD) technology for centralised treatment facility. The MoVap™ unit is a solution specifically designed for the growing frac and produced waste water treatment needs
Private	ATLETA INC.	United States	Not listed	NR	NR	AltelaRain® technology desalinates and decontaminates produced water without the energy intensive equipment, high temperatures or pressure of other water desalination technologies. It uses a highly efficient process of thermal distillation, which captures the heat generated by condensation and uses it for evaporation (a la rainwater).
CAM US	CAMERON	United States	11,584.54	CAM	BUY	Dominant position in the NAM produced water management market (c.50% market share): strong in oil and water separation, induced gas flotation and nutshell filtration. Their frac trees, frac isolation systems, and well testing and flowback equipment are backed by service expertise which maximises efficiency and reduces wellsite footprint and project complexity.
CHK US	CHESAPEAKE ENERGY	United States	18,534.60	CHK	XRWV	Green Frac program calls for the elimination of any chemical not critical to the drilling process. Through the program, the company has eliminated 25% of the chemicals previously used in the fracking process. In addition, Chesapeake is actively searching for safer alternatives for the remaining chemicals.
ESPH US	ECOSPHERE TECHNOLOGIES, INC.	United States	65.28	NR	NR	Diversified water engineering and services company focused on the NG industry and providing energy companies with chemical-free water reclamation that allows them to recycle 100% of flowback and produced waters. Ozonix oxidation technologies combine ozone (as a disinfectant), hydrodynamic cavitation, acoustic cavitation and electro-oxidation in a piece of equipment used to destroy bacteria, organics, and contaminants – and allows operators to re-use 100% of the water. Over 19mn bbl treated.
Private	Filterbox	Canada	Not listed	NR	NR	Packaged water treatment company offering technologies to non-conventional O&G on an equipment sale or rental/design-BOO basis
Private	FILTERBOXX	Canada	Not listed-	NR	NR	Offers technologies to non-conventional O&G on an equipment sale or rental/design-BOO basis. Experience in treating process water. Designs and builds skid mounted and/or containerized (S Series, and C Series) portable, packaged water and wastewater solutions
GSFV US	GASFRAC	Canada	525.03	NR	NR	Dedicated to efficient and environmentally friendly, virtually waterless fracking. The company uses LPG in gel form, as opposed to water, to extract natural gas which reduces or eliminates many of the environmental issues associated with hydraulic fracturing. GasFrac claims the proprietary technology enhances well productivity as well as eliminates any possible reservoir contamination.
GE US	GENERAL ELECTRIC	United States	163,384.45	GE	NEUTRAL	Developed a mobile evaporator designed to help drillers recycle waste water produced during fracking on site (vs. trucking the

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Table 2: Water & Wastewater treatment solutions providers

Ticker	Name	Country	MCap (USD Mn)	BofAML Ticker	BofAML Rating	Green shale gas exposure
HEK US	HECKMANN CORP	United States	632.66	NR	NR	water to a treatment plant). It can be mounted on a truck and driven to any well site, can process about 50 gallons a minute and is well suited for the Marcellus shale, where the water tends to come back with a high degree of dissolved solids.
Private	HYDRATION TECHNOLOGIES INC	United States	Not listed	NR	NR	Services-based company focused on total water solutions for shale. Heckman Water Resources provides water disposal, trucking, fluids handling, treatment and pipeline transport facilities (for water), and water infrastructure services
KRA1V FH	KEMIRA OYJ	Finland		KMRAF	NR	Forward Osmosis filtration technology specialist for reclaiming drilling wastewater from gas exploration operations. It has developed an alternative energy-driven means of filtering gas well reserve pit drilling water. Its technology reclaims drilling wastewater by using a unique filtration technology and harnessing a chemical energy source required by downstream E&P processes, a cost and resource that is already being consumed on each well.
LIN GR	LINDE	Germany	23,570.58	LNAGF	NEUTRAL	It has knowledge of both water-based and oil-based muds and can offer products to help solve the growing mud use and disposal markets in water-based fluids. Focusing on: chemistries that reduce environmental impact (its polymers can reduce the amount of energy required to fracture a well by 75%); materials that perform well in high brine (return water) enabling re-use and reduction of net water use; and new technologies for sustainable use of water in hydraulic fracturing applications
Private	MIOX CORPORATION	United States	Not listed	NR	NR	Provides a wide range of services for the natural gas industry. They don't drill the wells, but prepare the well pad for the drilling companies. They lay pipeline for the gas companies to transport their natural gas from the wells, called midstream lines, in that they connect the wellheads from the individual wells with larger transmission lines. They construct compressor stations, and do some horizontal directional drilling to take gas lines under roads or wetlands when necessary.
NLC US	NALCO HOLDING	United States	4,826.62	NLC	HOLD	Eco-friendly technology uses salt, water and power to generate a safe water disinfectant on site, eliminating the need to purchase, transport and store dangerous chemicals. On-site generation cuts transportation requirements by up to 80%, reduces carbon emissions and fuel consumption, and eliminates the storage and disposal of chemical containers.
RRC US	RANGE RESOURCES	United States	10,734.89	RRC	BUY	It has established a set of comprehensive standards in which a chemical cannot contain: any BTEX, carcinogens, teratogens, reproductive toxins; any priority pollutants (U.S. EPA List 40, CFR) or US EPA Safe Drinking Water Act contaminants; chemicals that would be considered persistent, bioaccumulating, or toxic by North Sea standards. The Nalco Adomite Research Group has also brought its expertise in water and polymers to bear on the compatibility concern, i.e. will the fracturing chemical additives be compatible with the high-TDS produced water.
SIE GR	SIEMENS	Germany	82,700.70	SMAWF	NEUTRAL	Reduced both the number and amount of chemicals it uses for Fracking from 0.5% to 0.1% of fracking fluid. Pioneered a water recycling program in Pennsylvania and is nearly at a 100% recycling rate for the water used in hydraulic fracturing.

Table 2: Water & Wastewater treatment solutions providers

Ticker	Name	Country	MCap (USD Mn)	BofAML Ticker	BofAML Rating	Green shale gas exposure
TCW CN	TRICAN WELL SERVICES	Canada	2,448.00	YTCW	XRWW	Floating Sand is a new product it has designed specifically for shale gas which allows it to float any type of proppant in non-viscous water, which will prevent sand from settling to the bottom of the fracture. It is particularly applicable in fracturing shales with slick water type treatments. It has also designed an enhanced emulsified CO2 system that allows the company to place very large fracturing treatments (100 tonnes-plus) into water-sensitive shales.
VIE FP	VEOLIA	France	7,809.88	VEOEF	BUY	World's leading water treatment company with c. 8% of the Nam primary and secondary produced water treatment market. Strong position in tertiary treatment. VWS offer includes i) thermal evaporation and crystallization technology as the primary treatment for both flowback and produced water from fracking, offering zero discharge liquid (95% of effluent recovered for reuse); ii) Optimized Pretreatment and Unique Separation (oil removal followed by degasification, chemical softening, media filtration, and reverse osmosis); and iii) MULTIFLO, mobile water softening designs for shale which enable reuse of the treated water in fracking operations, decreasing the demand for fresh supply water. The mobile units can treat up to 10,000 barrels per day of Produced and Frac Flowback Water.
Private	WATERTECHNICS	United States	Not listed	NR	NR	Onsite water treatment technology and services company. High volume recovery technologies for O&G industry (e.g. flowback, frac, and produced water for reuse). Chemical-free Wavelonics electric coagulation system can handle up to 50,000bpd.
WEIR LN	WEIR GROUP	United Kingdom	5,811.31	WEIGF	BUY	Weir SPM is a market leader in well service pumps and high pressure flow control equipment. Its line of reciprocating plungers and pumps are used in various applications including cementing, acidizing, and fracturing. The expanding flow control product line features products used to safely transport fluids at high pressure into the wellbore during various well service applications. It should benefit from frac sit evolution: shorter pump life expectancy; more repair and replacement of spares. Shale gas JV in China with Shengli Oilfield Highland Petroleum Equipment Co. Ltd.

Source: Companies, BofA Merrill Lynch Global Research, Bloomberg. GWI. NR = not covered or rated by BofAML Global Research. MCap data as at 26/09/11

"Green" fracking fluids need to meet or exceed standards of the US Safe Drinking Water Act – ie, only traces of toxins such as benzene, toluene, ethylbenzene and zilene

Green(er) fracking chemicals, a rapidly emerging market

With shale gas set for ongoing significant growth, new opportunities will arise for integrated O&G services and chemicals companies that are working on more environmentally friendly frac / completion fluids, especially in areas close to communities and drinking water supply. We anticipate that green fracking fluids will gain an increasing proportion of the c.US\$8.3bn completion fluid market. This includes water-based fluids which have lower environmental impacts, and even fluids made from materials used in processed food, which allegedly meet FDA standards for consumption. We anticipate that demand and prices will increase for green fracking fluids.

Table 3: Green fracking chemical solutions providers

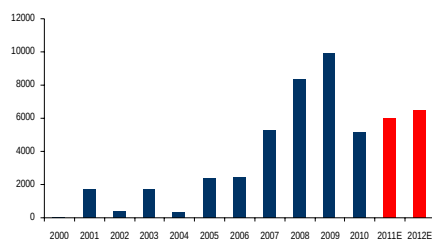
Ticker	Name	Country	MCap (US\$ Mn)	BofAML Ticker	BofAML Rating	Green shale gas exposure
BHI US	BAKER HUGHES	United States	23,666.11	BHI	Buy	Launched its BJ SmartCare family of environmentally friendly fracking fluids and additives (e.g. water-based). The offering has been qualified through a recognised third-party chemical evaluation process. It is the no.3 player in the completion fluids market.
BAS GR	BASF	Germany	56,908.94	BFFAF	Neutral	Oilfield division provides: i) drilling fluid additives (focuses on products for water-based drilling fluids; Polydrill®it minimise the

Table 3: Green fracking chemical solutions providers

Ticker	Name	Country	MCap (US\$ Mn)	BofAML Ticker	BofAML Rating	Green shale gas exposure
FTK US	FLOTEK INDUSTRIES IN	United States	249.84	NR	NR	loss of water from the drilling fluid on the way into the geological formation); ii) cementing additives (reliable cementing); and iii) stimulation additives (reduced water loss, biocides)
HAL US	HALLIBURTON	United States	30,888.97	HAL	Buy	Downhole equipment, specialty chemicals and equipment for cementing and stimulation for oilfield services companies. It has several catalysts for environmentally friendly nano-fluids (microemulsifiers), which it claims can improve production and reservoir integrity – e.g. sells a fracking fluid made from citrus. Looking for growth in NAM, Poland, Turkey, Paris basin. Has also developed a water-based shale specific fluid called SHALEDRIIL. New green fracking line: i) CleanStim, a fracking fluid composed entirely of ingredients found in processed foods, which is said to provide excellent performance in terms of pumpability, proppant transport and retained conductivity; ii) CleanStream Service which uses UV light to kill bacteria that can form in the well; and iii) CleanWave which uses a portable electrocoagulation component that binds with water contaminants and forces them either to the surface where they can be removed by a skimmer, or to the bottom of the tank leaving clear water above suitable for reuse in drilling and production operations. The technique minimizes fresh water consumption and costs associated with procurement and disposal. HAL is the no.2 player in the completion fluids market.
NR US	NEWPARK RESOURCES	United States	601.29	NR	NR	Newpark Drilling Fluids and Environmental Services accounts for 83% of company revenues. Provides environmental services to the O&G industry. Its proprietary Deepdrill and Evolution water-based drilling fluids are said to be more environmentally friendly, safer and easier to use than oil-based mud systems. Newpark claims this product increases the rate of penetration and reduces operating expenses. It is the no.4 player in the completion fluids market.
SLB US	SCHLUMBERGER	United States	85,374.47	SLB	Buy	Number of water-based systems compatible with shale gas. It is the no.1 player in the completion fluids market.
TTI US	TETRA TECHNOLOGIES	United States	662.20	NR	NR	Energy services company with integrated chemicals operation supplying the energy industry. Completion fluids is the second-largest source of revenues.

Source: Companies, BofA Merrill Lynch Global Research, Bloomberg. GWI. NR = not covered or rated by BofAML Global Research. MCap data as at 26/09/11

Chart 4: US wind installations



Source: AWEA? BofA Merrill Lynch Global Research

Renewables, a positive spark for the sector

Part of our analysts' bearish stance on the renewable sector relates to the prevailing low US gas price, which makes wind and solar relatively less competitive and has served to reduce demand. Should gas prices move higher on the back of tougher HSE standards for shale gas, then they would become incrementally more positive on the renewable sector. This group includes wind turbine manufacturers such as Vestas and Hansen; solar manufacturers with an interesting US franchise such as First Solar and Sunpower; and renewable developers with US pipelines or installed merchant assets such as EDP Renovaveis, Iberdrola and NextEra. Certain utility companies could also benefit from higher gas prices, for example GDF Suez (higher LNG price for US imports from the Middle East) and International Power (gas power plants exposed to merchant power prices).

Table 4: Renewables / Utilities companies that could benefit from shale gas HSE regulation - Share price performance

As at COB	Wed 21 Sep 11				Mkt Cap		Free float		EV FY1		Share Price Performance (LC)		
Company	Ticker	Rating	FY1 Year		LC mn	USD mn	%	USD mn	LC mn	USD mn	-1w Abs	-3m Abs	YTD Abs
EDP Renovaveis	EDRVF	BUY	C-1-9	DEC-2011	3,636	4,978	22	1,118	7,708	10,553	-2.0%	1.2%	-0.5%
First Solar	FSLR	BUY	C-1-9	DEC-2011	6,345	6,345	NA	NA	5,819	5,819	-18.8%	-36.9%	-43.9%

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Table 4: Renewables / Utilities companies that could benefit from shale gas HSE regulation - Share price performance

As at COB	Wed 21 Sep 11				Mkt Cap		Free float		EV FY1		Share Price Performance (LC)		
Company	Ticker	Rating	FY1 Year		LC mn	USD mn	%	USD mn	LC mn	USD mn	-1w Abs	-3m Abs	YTD Abs
GDF SUEZ	GDSZF	BUY	B-1-7	DEC-2011	44,813	61,353	55	33,821	99,870	136,732	-0.4%	-12.6%	-21.1%
Hansen	HSNTF	RSTR**	RSTR**	MAR-2012	437	599	NA	NA	NA	NA	2.7%	63.0%	9.1%
Iberdrola	IBDSF	NEUTRAL	A-2-7	DEC-2011	27,365	37,466	61	22,761	61,341	83,982	-1.8%	-15.8%	-14.0%
Internat'l Power	IPRWF	BUY	A-1-8	DEC-2011	15,878	24,781	30	7,475	15,978	24,938	-1.9%	6.5%	-3.4%
NextEra Energy	NEE	BUY	B-1-7	DEC-2011	23,148	23,148	NA	NA	42,977	42,977	0.9%	-3.2%	5.5%
SunPower Corp.	SPWRA	UNDERPERFORM	C-3-9	DEC-2011	6,345	955	32	302	1,175	1,175	-20.4%	-43.7%	-26.7%
Vestas	VWSYF	UNDERPERFORM	C-3-9	DEC-2011	17,345	23,748	100	23,748	18,945	25,937	-9.0%	-19.8%	-48.8%

Source: BofA Merrill Lynch Global Research

Table 5: Renewables / Utilities companies that could benefit from shale gas HSE regulation - Stock valuation multiples

As at COB	Wed 21 Sep 11	P/E				Gross Yield				FCF Yield				EV/EBITDA				Price
Company	Ticker	2010	FY11e	FY12e	FY13e	2010	FY11e	FY12e	FY13e	2010	FY11e	FY12e	FY13e	2010	FY11e	FY12e	FY13e	Book
EDP Renovaveis	EDRVF	47.1x	28.7x	25.9x	19.4x	0.0%	0.0%	0.8%	1.0%	-19.6%	-22.3%	-9.3%	-3.0%	10.8x	10.7x	9.6x	8.6x	0.7x
First Solar	FSLR	9.6x	8.8x	6.8x	6.1x	0.0%	0.0%	0.0%	0.0%	1.8%	-6.6%	0.3%	0.9%	6.4x	5.5x	4.2x	3.5x	2.4x
GDF SUEZ	GDSZF	10.3x	11.8x	9.8x	8.6x	7.2%	7.2%	7.4%	7.7%	2.1%	6.2%	10.9%	16.7%	6.6x	6.4x	5.7x	5.1x	0.8x
Hansen	HSNTF	NA	NA	NA	NA	0.0%	0.0%	NA	NA	1.7%	17.4%	NA	NA	1053.6x	1063.1x	NA	NA	0.7x
Iberdrola	IBDSF	10.1x	9.8x	8.9x	8.6x	6.6%	6.8%	7.0%	7.2%	-2.1%	2.0%	4.0%	6.3%	7.5x	6.7x	5.9x	5.4x	1.0x
Internat'l Power	IPRWF	15.7x	13.9x	12.0x	9.8x	3.3%	2.9%	3.3%	4.1%	-0.5%	-2.4%	5.9%	12.2%	4.3x	4.3x	3.8x	3.1x	1.1x
NextEra Energy	NEE	12.7x	12.6x	11.7x	11.2x	3.6%	4.0%	4.2%	4.4%	-9.6%	-4.6%	-7.3%	0.4%	8.8x	9.2x	8.8x	8.4x	1.8x
SunPower Corp.	SPWRA	4.9x	8.3x	6.0x	NA	0.0%	0.0%	0.0%	NA	5.0%	-26.2%	-3.7%	NA	4.2x	11.8x	8.0x	NA	0.7x
Vestas	VWSYF	117.7x	67.8x	60.0x	NA	0.0%	0.0%	0.0%	NA	-3.9%	-1.1%	-1.1%	NA	32.2x	25.2x	23.2x	NA	7.2x

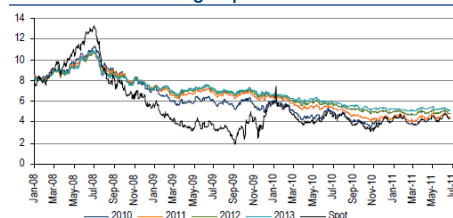
Source: BofA Merrill Lynch Global Research

Table 6: Renewables / Utilities companies that could benefit from shale gas HSE regulation - BofAML forecasts

As at COB	Wed 21 Sep 11		EPS				EPS	DPS				DPS	EBITDA (in bn)				EBITDA	EcoDebt/ EBITDA			
Company	Ticker	CNRY	2010	FY11e	FY12e	FY13e	4Y CAGR	2010	FY11e	FY12e	FY13e	4Y CAGR	2010	FY11e	FY12e	FY13e	4Y CAGR	2010	FY11e	FY12e	FY13e
EDP Renovaveis	EDRVF	EUR	0.09	0.15	0.17	0.22	14.4%	NA	NA	0.03	0.04	NA	0.7	0.8	0.94	1.07	18.4%	62.5x	60.2x	56.3x	52.6x
First Solar	FSLR	USD	7.68	8.40	10.75	12.05	12.5%	NA	NA	NA	NA	NA	0.9	1.1	1.49	1.76	21.4%	-0.6x	-0.2x	-0.1x	-0.1x
GDF SUEZ	GDSZF	EUR	2.04	1.78	2.14	2.45	3.5%	1.50	1.50	1.56	1.62	2.5%	15.2	17.1	18.97	20.40	9.9%	2.5x	2.4x	2.1x	1.8x
Hansen	HSNTF	EUR	0.01	0.02	NA	NA	NA	NA	NA	NA	NA	NA	0.0	0.0	NA	NA	NA	801.3x	807.8x	NA	NA
Iberdrola	IBDSF	EUR	0.49	0.50	0.55	0.57	3.1%	0.33	0.33	0.35	0.35	1.5%	8.2	8.7	9.46	9.91	7.2%	5.4x	4.9x	4.2x	3.8x
Internat'l Power	IPRWF	GBP	20.81	23.58	27.14	33.29	13.7%	10.90	9.43	10.86	13.32	1.5%	3.7	4.0	4.38	4.91	11.6%	7.0x	6.8x	6.1x	5.3x
NextEra Energy	NEE	USD	4.30	4.36	4.70	4.89	4.8%	1.98	2.20	2.31	2.43	6.5%	4.9	4.8	5.26	5.57	6.4%	6.8x	7.2x	6.9x	6.6x
SunPower Corp.	SPWRA	USD	1.95	1.15	1.60	NA	NA	NA	NA	NA	NA	NA	0.3	0.1	0.21	NA	NA	25.6x	62.0x	42.9x	NA
Vestas	VWSYF	EUR	0.77	1.33	1.50	NA	NA	NA	NA	NA	NA	NA	0.6	0.8	0.84	NA	NA	1.1x	1.1x	1.3x	NA

Source: BofA Merrill Lynch Global Research

Chart 5: US natural gas prices



Source: Bloomberg

Putting gas prices in perspective

To put the current gas price of c.\$3.70-4.0/MMBtu into perspective, we believe that wind and solar would need gas prices of US\$8-12/MMBtu to be competitive without subsidies, although after tax credits are considered this cost comes down to US\$6-9/MMBtu. At the peak of the market in 2008, gas prices of over US\$10/MMBtu were high enough to justify building merchant wind farms, and these accounted for around 30% of 10GW US wind demand. In our view, the fall in gas prices (and the flattening of the forward curve) has been an important reason for the limited recovery in wind demand so far, with 2011 installations of just 6GW expected. This has led to a utilisation rate at the turbine manufacturers of roughly 50% and utilities being forced to scale back their capex/growth ambitions. A recovery in wind demand could be played through the turbine supply chain or via the utilities with large US pipelines. A higher gas price would certainly help the economics of solar but the technology is far from being competitive. We think that wind technology needs to substantially reduce its costs before we will see an inflexion of demand.

Shale gas revolution

Unconventional gas boom

The past few years have seen a revolution in gas supplies driven by a boom in the production of unconventional gas resources such as shale gas, tight gas and coal bed methane. Many countries are looking to unconventional gas to develop secure and sustainable energy supply and to reduce GHG emissions. Global gas demand is expected to rise by 60% by 2035, according to the IEA.

Shale gas has revitalised the US NG industry

The combination of horizontal drilling and hydraulic fracturing ("fracking") has granted access to large volumes of shale gas that were previously uneconomical to produce. The production of NG from shale formations has rejuvenated the natural gas industry in the US – and North American unconventional gas reserves are large enough to meet domestic demand for the next century. It has also sparked interest in gas shales in Canada, Europe, Asia, MENA and Australia, among other areas.

Fracking is likely to mean increased scrutiny, regulation & costs

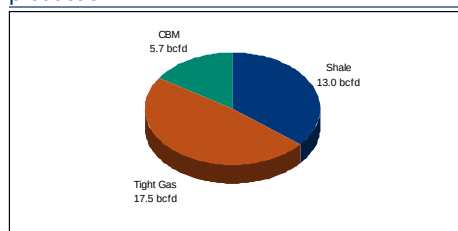
Concerns about hydraulic fracturing ("fracking"), the method used to extract natural gas from shale rock, has resulted in bans or proposed bans on the method in several jurisdictions. We anticipate that regulators will follow stakeholders in trying to seek a balance between producing shale gas economically and minimising HSE concerns. Either way, the result should be the same, with oil & gas companies facing the prospect of stricter safety regulations and higher production costs.

Table 7: Unconventional gas primer

Issue	Overview
What is it?	Natural gas from reservoirs with low permeability
Types	Shale gas, Tight gas, Coal bed methane
Difference from conventional gas	Shale gas reservoirs require successful stimulation (fracturing/fracking) to be produced
Cost	Unconventional gas breakeven at US\$4-6/mmBtu vs breakeven of US\$1.5-3/mmBtu for conventional gas Key cost elements: drilling & completion; finding cost; initial production (IP)/Expected ultimate recovery (EUR)
How much is there?	2,500 trillion cubic feet (TCF) of shale gas resources in the US – enough to supply the US for 110 years at current consumption
Why has the US led the way?	Better geology (shallower deposits), lax regulatory framework (initially), low taxation, good access to technology and infrastructure

Source: BofA Merrill Lynch Global Research

Chart 6: Est. 2011 global unconventional gas production



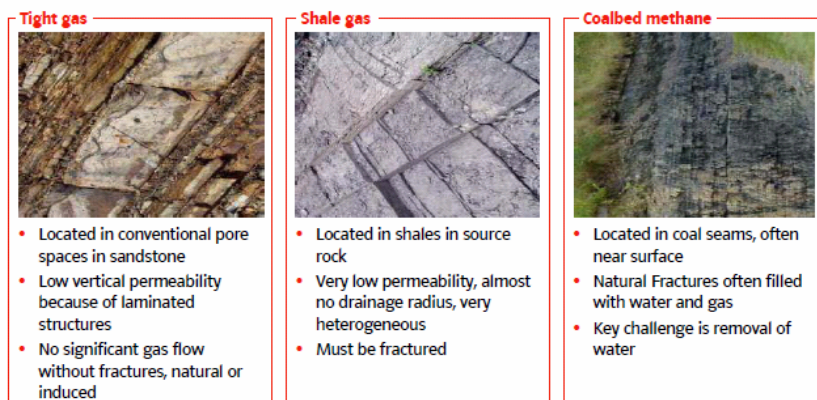
Source: Wood Mackenzie, BofA Merrill Lynch Global Research

Unconventional gas boom

There are three main sources of unconventional gas:

- 1) **Tight gas:** Gas trapped in impermeable and non porous sandstones
- 2) **Coalbed Methane (CBM):** Formed in low permeability coal seams and absorbed by coal particles
- 3) **Shale gas:** Formed in shale rock (fine grained rock) and held by clay particles or in pores and cracks

Chart 7: Types of unconventional gas

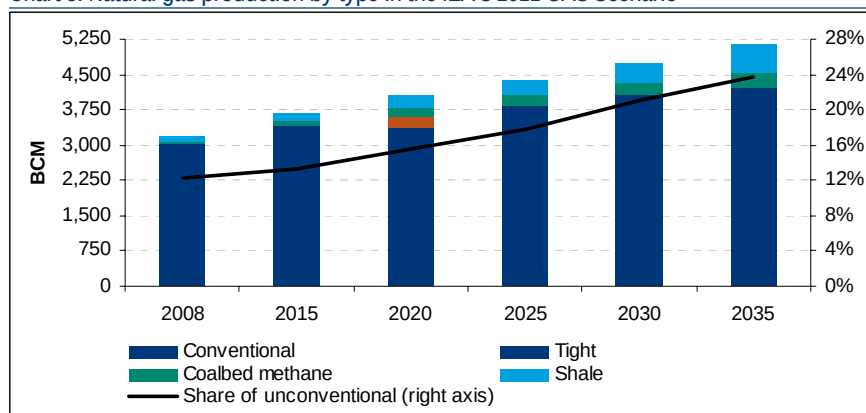


Source: E.ON

Up to 11% of global production by 2035

According to the IEA's World Energy Outlook 2011 (*Are We Entering a Global Age of Gas?*), most of the increase in unconventional gas production comes from shale gas and CBM. The IEA predicts that the share of shale gas in global gas production will reach 11% in 2035. In North America, unconventional gas – mostly shale gas – could increase from accounting for less than half of overall gas production in 2008 to nearly two-thirds in 2035 (Source: IEA).

Chart 8: Natural gas production by type in the IEA's 2011 GAS Scenario*



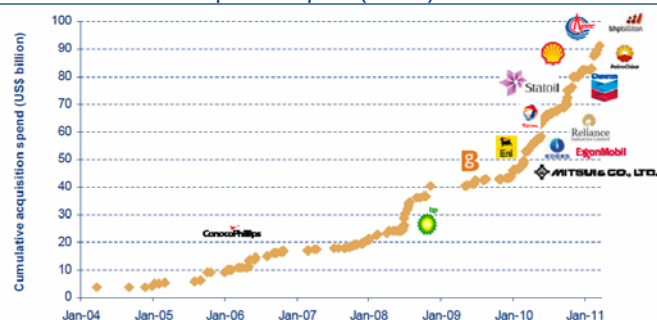
Source: IEA. * The GAS scenario departs from the 2010 WEO base scenario by incorporating a combination of new assumptions that underpin a more positive future outlook for gas.

Growing industry interest in unconventional gas

This has sparked growing industry interest in unconventional gas, with independents featuring prominently and the majors significantly stepping up their acquisitions in the area over the past three years.

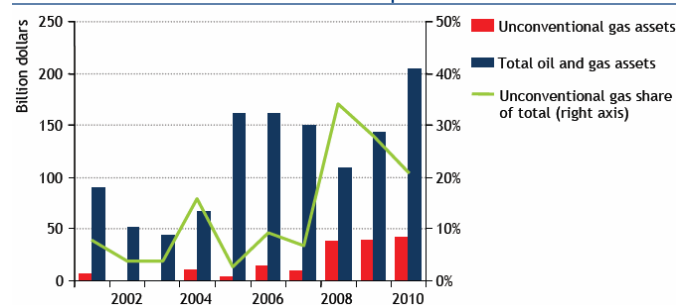
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Chart 9: Cumulative acquisition spend (US\$bn)



Source: Wood Mackenzie M&A database. * ExxonMobil/XTO deal excluded

Chart 10: Transaction values of O&G acquisitions



Source: IEA databases and analysis, BofA Merrill Lynch Global research

Changing landscape but independents still feature

Table 8: US natural gas production by player (in mmcf/d)

Company	Ticker	2Q'11	1Q'11	2Q'10	2Q'11 vs. 1Q'11 % Change	2Q'11 vs. 2Q'10 % Change	2010 Reported U.S. Net Proved Liquids Reserves	RP Ratio	Proved U.S. Liquids Reserves Ranking	U.S. Liquids Rigs Drilling on 8/26/11	U.S. Liquids Rigs Drilling on 1/1/10	U.S. Liquids Rigs % Drilling Change Since 1/1/10
1 ExxonMobil	XOM	3,842	3,904	3,810	-1.60%	0.80%	26,111	19	1	49	52	-6%
2 Chesapeake	CHK	2,575	2,703	2,497	-4.70%	3.10%	15,455	16	2	84	110	-24%
3 Anadarko	APC	2,326	2,412	2,324	-3.60%	0.10%	8,117	10	6	32	24	33%
4 Devon	DVN	2,029	1,964	1,982	3.30%	2.40%	9,065	12	5	44	34	29%
5 EnCana	ECA	1,864	1,801	1,805	3.50%	3.30%	7,477	11	7	32	40	-20%
6 BP	BP	1,833	1,905	2,240	-3.80%	-18.20%	13,743	21	3	12	12	0%
7 ConocoPhillips	COP	1,651	1,589	1,822	3.90%	-9.40%	10,479	17	4	14	10	40%
8 Southwestern	SWN	1,347	1,277	1,077	5.50%	25.10%	4,930	10	9	15	16	-6%
9 Chevron	CVX	1,299	1,270	1,317	2.30%	-1.40%	2,472	5	18	2	1	100%
10 Williams	WMB	1,170	1,155	1,110	1.30%	5.40%	4,272	10	10	17	14	21%
11 EOG	EOG	1,114	1,134	1,069	-1.80%	4.20%	6,491	16	8	13	31	-58%
12 BHP(6)	BHP	907	743	599	22.10%	51.50%	3,110	9	12	24	19	26%
13 Shell	RDS	903	1,003	1,145	-10.00%	-21.10%	2,671	8	15	21	14	50%
14 Apache	APA	880	858	675	2.60%	30.40%	2,937	9	14	7	8	-13%
15 Occidental	OXY	761	734	681	3.70%	11.70%	3,034	11	13	0	0	0%
16 El Paso	EP	676	677	636	-0.10%	6.30%	2,396	10	19	6	8	-25%
17 Ultra	UPL	627	600	554	4.40%	13.20%	4,200	18	11	8	11	-27%
18 QEP	QEP	626	659	525	-5.00%	19.30%	2,613	11	16	12	15	-20%
19 Newfield	NFX	516	503	564	2.60%	-8.40%	2,492	13	17	11	14	-21%
20 EXCO	XCO	489	395	281	23.80%	74.10%	1,499	8	20	27	13	108%
Totals/Average		27,436	27,287	26,712	0.50%	2.70%	133,564			430	446	-4%
Others										439	358	23%
Total										869	804	8%

Source: Chesapeake Energy, BofA Merrill Lynch Global research

Table 9: Remaining recoverable resources of shale gas

Region	Tcm*
E. Europe & Eurasia	<5
Middle East	14
Asia Oacific	51
OECD NAM	55
Latin Am	35
Africa	29
OECD Europe	16
World	204

Source: IEA WEO 2011.

Shale gas Primer

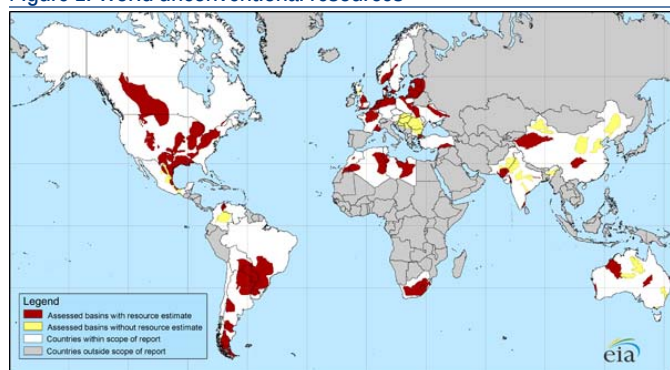
What is shale gas?

Shale gas refers to natural gas that is trapped within shale formations. Shales are fine-grained sedimentary rocks that can be rich sources of petroleum and natural gas. The IEA estimates that the recoverable resources of shale gas amount to 204 tcm – equivalent to over 60 years of current annual conventional gas production.

Where is shale gas found?

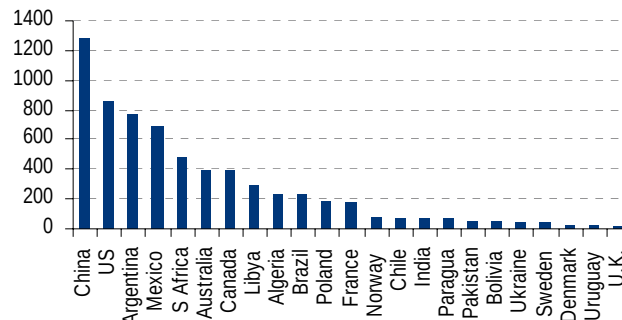
Shale gas is found in shale "plays", which are shale formations containing significant accumulations of natural gas and which share similar geologic and geographic properties. Surveyors and geologists identify suitable well locations in areas with potential for economical gas production by using both surface-level observation techniques and computer-generated maps of the subsurface. There are currently an estimated 48 shale basins in 32 countries.

Figure 1: World unconventional resources



Source: EIA

Chart 11: Technically recoverable shale gas resources (Tcf) globally



Source: EIA 2011

How is shale gas produced?

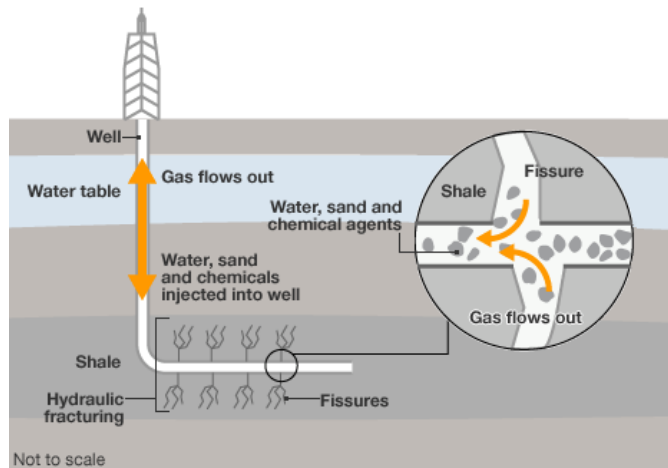
Because shales usually have insufficient permeability to allow significant fluid flow to a well bore, most are not commercial sources of NG. Shale has low matrix permeability, so gas production in commercial quantities requires fractures to create this. The US shale gas boom has largely been based on innovations in drilling techniques, which have allowed oil services companies to access gas by making use of pioneering technological developments such as hydraulic fracturing (fracking), to create extensive artificial fractures around well bores:

1. **A vertical well is drilled** to the targeted rock formation.
2. **Horizontal drilling is then used** to provide greater exposure to the oil/gas contained shale, with lateral lengths up to 3,000m (10,000 feet) within the shale, to create maximum borehole surface area in contact with the shale.
3. **While drilling, cementing is carried out** between the drill pipe and well surface to prevent fluids escaping.
4. **Hydraulic fracturing (commonly called "fracking" or "hydrofracking")** is done, where water chemicals and sand (or other granular products, called proppants) are pumped into the well to unlock the hydrocarbons trapped in shale formations by opening cracks (fractures) in the rock and allowing NG to flow from the shale into the well.

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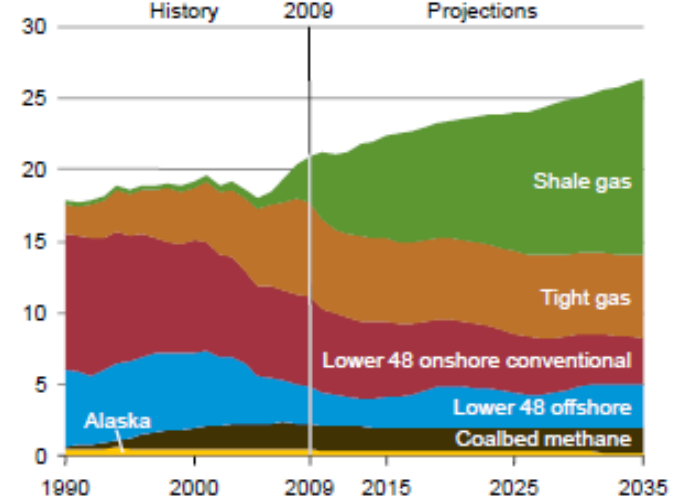
Chart 12: With technical advances in shale gas production...

Shale gas extraction



Source: Baker Hughes, BofAML Global Research

Chart 13: ... US natural gas production (Tcf per year) is rising

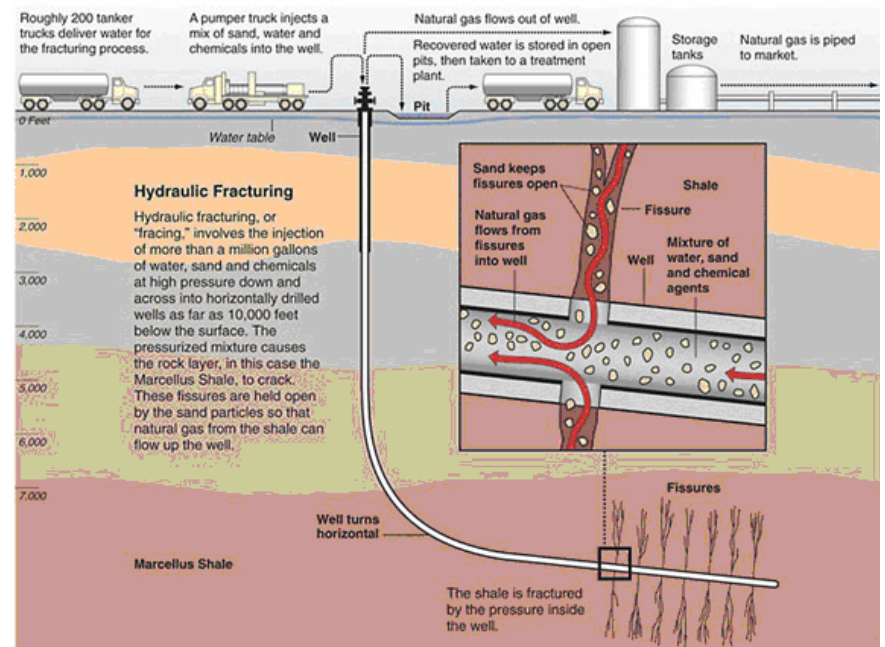


Source: Baker Hughes, BofAML Global Research

Fracking enables cost-effective extraction

When used in conjunction with horizontal drilling, hydraulic fracturing enables gas producers to extract shale gas at reasonable cost. Without these techniques, natural gas does not flow to the well rapidly, and commercial quantities cannot be produced from shale.

Chart 14: Overview of a typical hydraulic fracking operation



Source: EIA

Chart 15: Conventional sandstone



Source: Wood Mackenzie

Chart 16: Shale



Source: Wood Mackenzie

How does shale gas production differ from conventional NG?

Conventional reservoirs are created when NG migrates toward the earth's surface from an organic-rich source formation into highly permeable reservoir rock, where it is trapped by an overlying layer of impermeable rock. In contrast, shale gas resources form within the organic-rich shale source rock. The low permeability of the shale greatly inhibits the gas from migrating to more permeable reservoir rocks. Without horizontal drilling and fracking, shale gas production would not be economically feasible because the NG would not flow from the formation at high enough rates to justify the cost of drilling.

Table 10: Conventional vs. shale gas

Conventional gas	Shale gas
Usually in discrete traps as independent or associated with oil	Usually found in formations with large volumes but low recovery (15-30%)
Easier to develop	Very complex to develop & completion can be uneconomic, but very few dry holes are drilled
The source, trap and reservoirs are different in this case	For some of the types the gas source, trap and reservoir are the same
80% recovery factor of gas in place	Wells produce at high initial rates that decline steeply

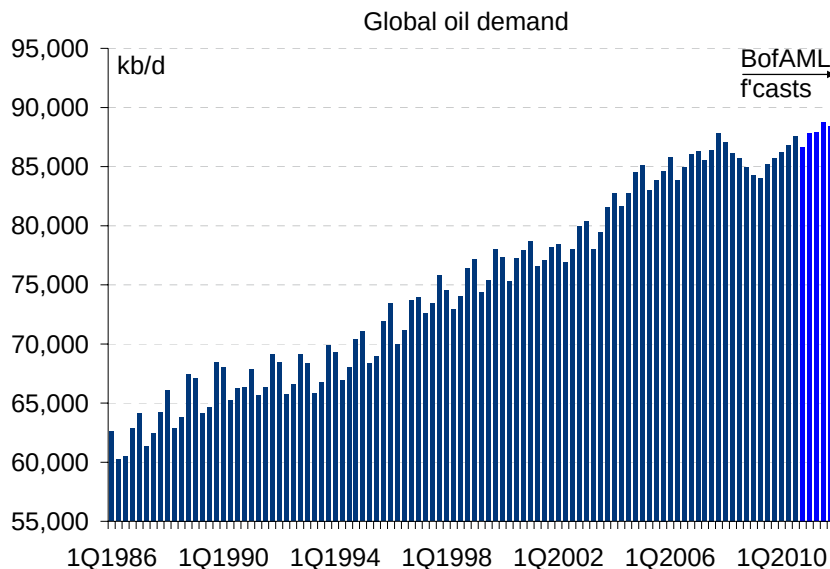
Source: Wood Mackenzie

Why does the world need shale gas?

With two-thirds of the 100 countries currently producing O&G liquids and the majority of global giant oil fields past their production peak, the world needs:

- **the equivalent of four to six more Saudi Arabias if it is to maintain current levels of production by 2030.** This, along with increasingly globalised competition for reserves, is pushing oil & gas companies towards more difficult types of hydrocarbons and increasingly complex E&P to meet growing global energy demand – such as shale gas.
- **a diversified supply mix, energy security and price stability:** Many countries are looking to shale gas in the context of the ongoing debate over supply diversification plans for their respective energy mix – and the twin goals of energy security and long-term price stability. For countries with high levels of energy insecurity, or reliance on a single supplier, domestic or imported shale gas production could help meet increased domestic consumption.

Chart 17: Global crude oil demand has been growing at among the fastest rates since 2005



Source: IEA, BofA Merrill Lynch Global research

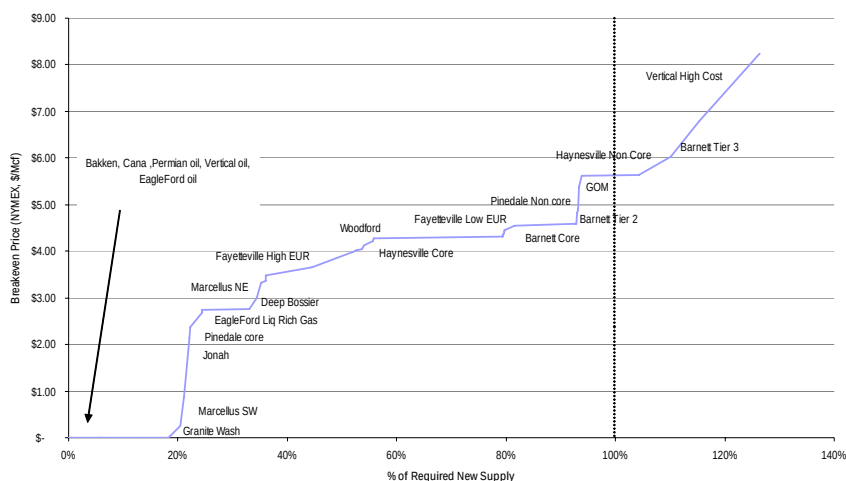
Economics of shale gas

Shale had long been considered uneconomic to develop because of very low rock permeability, which yielded wells with low production rates. However, the combination of horizontal drilling and fracking has allowed North America to achieve economic production rates of between US\$4/MBtu and US\$6/MBtu – which compares favourably with most sources of conventional gas (ie, US\$1.5/MBtu to US\$3/MBtu). The key cost elements are:

1. **Drilling & completion;**
2. **Finding cost;**
3. **Initial production (IP) / Expected ultimate recovery (EUR).**

In this report we explore the emerging costs associated with increased scrutiny and regulations around fracking.

Chart 18: Shale gas breakeven costs per area

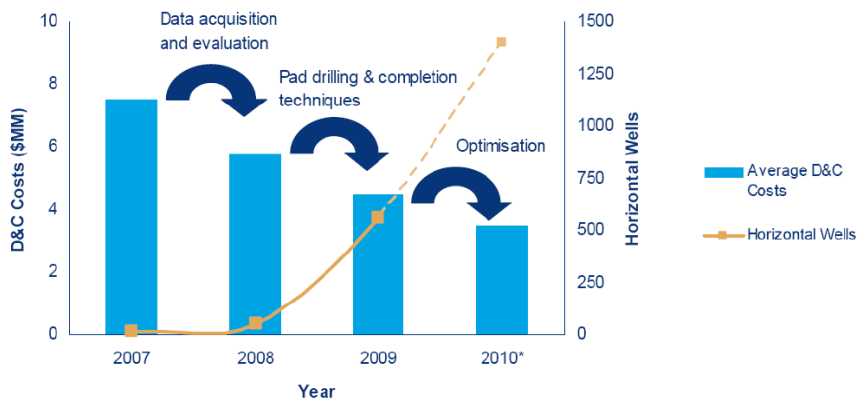


Source: BofA Merrill Lynch Global Research

Cost efficiencies over time

The US experience shows that costs will fall significantly as production increases and the benefits of experience, competition and economies of scale kick in.

Chart 19: Cost efficiencies in the Marcellus Shale in the US over time



Source: Centrica, Wood Mackenzie analysis of data from Pennsylvania DEP, Wright & Co.

The gas factory concept is commonly defined as employing multiple horizontal wells that are drilled, completed, tied in and produced from a single surface location, whereby an E&P company, along with its service providers, can optimise every part of the process

Gas factory production approach

Key in this regard is that shale gas producers are concentrating on lowering costs and streamlining operations via a “gas factory” approach to extraction.

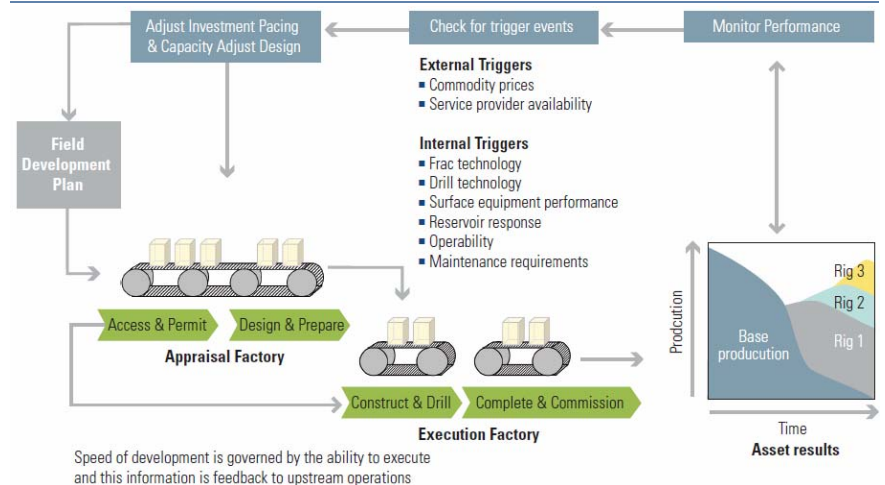
Table 11: Shale “gas factory” production approach

Concept	Overview
Multiple horizontal wells	At times more than 30
Centralised production facilities	Located on a single surface location, or pad
Use of pad drilling	Because of its efficiency (i.e. allows for simultaneous operation)s and “greener” characteristics (i.e. less infrastructure, transport)
High-performance, skid-mounted fit-for-purpose drilling rigs	NA
Conducting 24/7 hydraulic fracturing operations	NA
Leveraging economies of scale	Bulk deliveries of sand and steel casing
Redesigning fracture manifolds	To allow simultaneous work on each pad
Reducing wellhead size	NA
Expanding the use of supervisory control and data acquisition (SCADA) across fracture operations, coiled tubing operations, wireline operations and vis-à-vis safety	NA
Developing specialised technical staff	For manufacturing process
Partnering with other companies	Water treatment facilities, chemicals, coordinating testing
Using green completions	Capturing NG in the flow back stream after fracking (vs. venting or flaring it)

Source: BofA Merrill Lynch Global Research

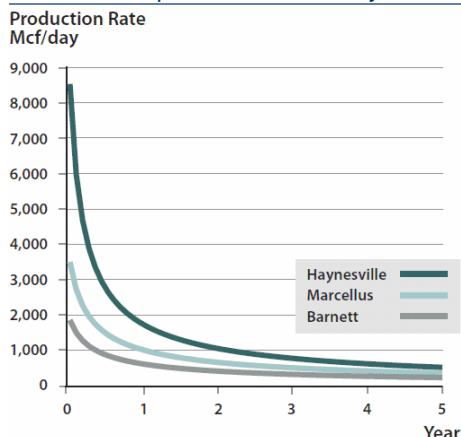
This manufacturing approach is still in its early days but the gas factory approach has led to high levels of capital and operating efficiency for those using it – with companies announcing up to a 40% reduction in drilling, completion and tie-in costs.

Chart 20: Economics – a gas factory production approach



Source: Schlumberger Business Consulting Analysis

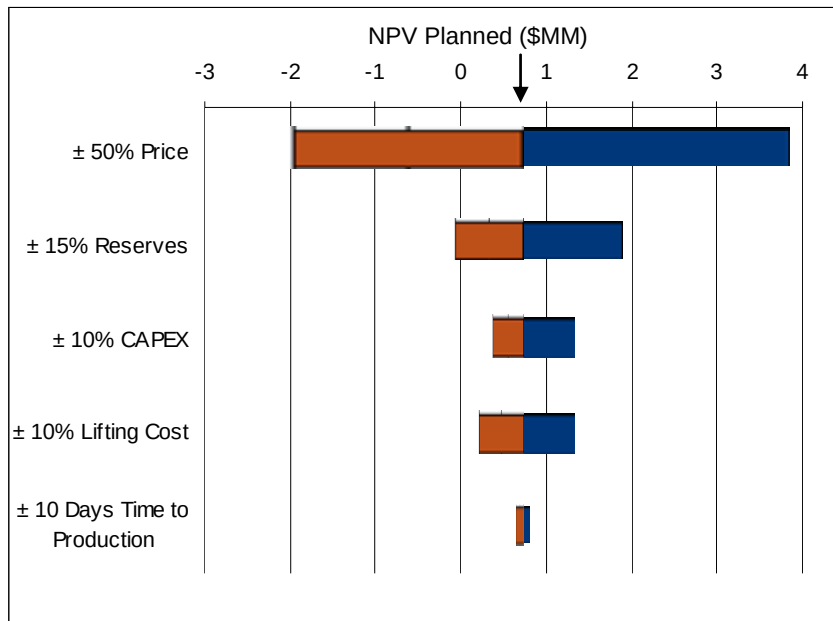
Chart 21: Initial production rate Mcf/day



Source: Schlumberger Business Consulting Analysis

With continuous technological improvement – and companies accelerating learning and applying different techniques between and even within shale basins – the gas factory approach should see costs continue to decline.

Chart 22: But initial production is crucial



Categories of Triggers

- Market Pricing
- Subsurface uncertainty
- Project execution Performance
- Supplier Performance
- Facility uptime

Source: Schlumberger Business Consulting Services

Economics outside the US could be more challenging

Among the factors which could challenge the economics of shale gas outside the US are:

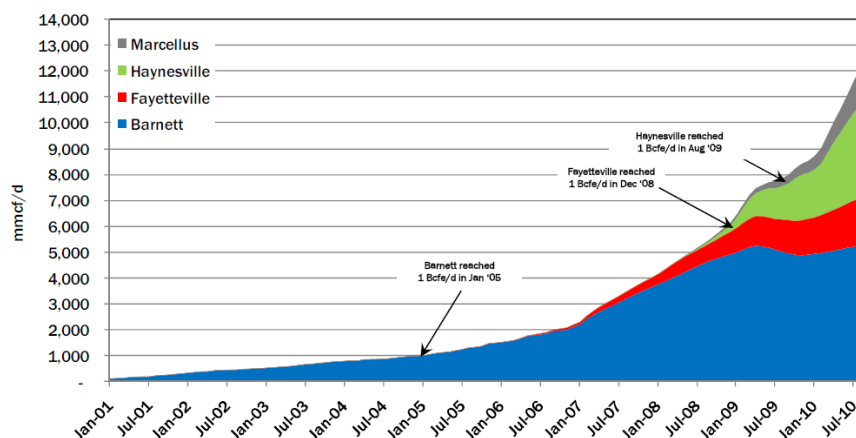
- The global supply chain (drilling rigs, fraccunits) is still in its infancy and lacks both the scale and the cost advantages of the US model. Rigs capable of drilling horizontally are also relatively scarce.
- Infrastructure to monetise the gas is not always accessible or available.
- Global supply of skilled labour can be scarce.
- In Europe and China, among other areas, unconventional gas deposits are located at depths of up to 2-4 miles, which is much deeper than the 1-2 mile depth drilling in the US.

Exponential growth in US shale gas activity

The current drive to harness US shale gas began in 2006 with the successful operations at Barnett Shale, Texas. As new wells were drilled and prospectivity improved with new technology, estimates of economically and technically recoverable resources rose. The success in Barnett and supportive NG prices at that point in time spurred more shale activity.

Between 2007 and 2010, US shale gas production tripled (advances in technology pushing down production costs) and its percentage contribution to domestic natural gas consumption increased from about 5% to over 20% – resulting in a parallel decline of 1.2Tcf of imports (ie, one-third) over this period.

Exhibit 1: US shale gross production Jan 2001 - Sept 2010



Source: Chesapeake, BofA Merrill Lynch Global Research

- **How much is there?:** 2,500 trillion cubic feet (Tcf) of shale gas resources in the US (Source: EIA) – enough to supply the US for 110 years at current consumption. Total production of shale gas is expected to triple by 2035.
- **Most active shale plays:** Barnett Shale, Haynesville/Bossier Shale, Antrim Shale, Fayetteville Shale, Marcellus Shale, and New Albany Shale.

Figure 2: US shale plays



Source: EIA

- **Why has the US led the way?:** Better geology (shallower deposits), lax regulatory framework (initially), low taxation, good access to technology and infrastructure (high power rigs, new drilling methods, efficiency).
- **Political impetus:** Shale gas is also being promoted owing to the US desire

for energy security, as well as President Obama's push for a Natural Gas Bill. GHG emissions are also at play, with Democrats and Republicans arguing shale gas's green credentials.

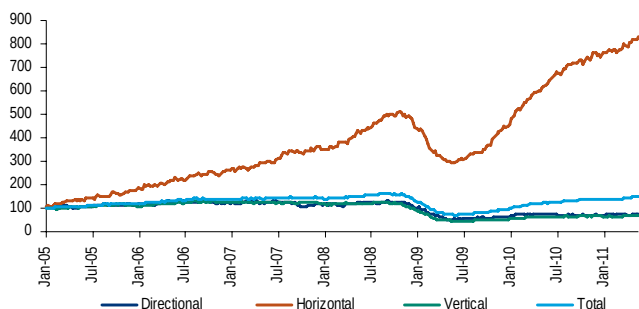
How much gas is there really? Take estimates with a pinch of salt

In August 2011, the US Geological Survey released its latest estimate of the amount of "undiscovered technically recoverable" natural gas in the Marcellus Shale formation. The estimated volume, around 84tcf, is 80% smaller than an estimate published earlier this year by the DoE's Energy Information Administration. This discrepancy has raised questions about how much shale gas there really is, how estimates are calculated, the dependence on industry estimates for calculations, and the possible evidence of greater risk and uncertainty around shale gas than some may previously have thought.

Technology has been key to US developments

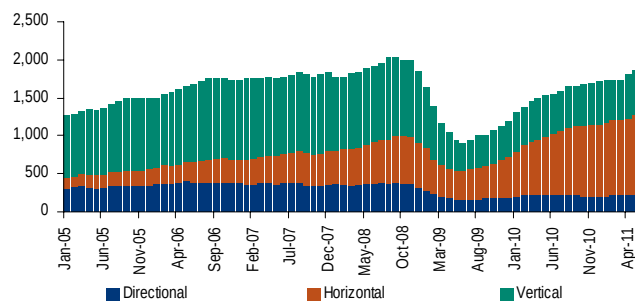
The key element of the success of North American shale gas production has, once again, been the combination of cost-effective horizontal drilling with fracking.

Chart 23: Growth in horizontal drilling (a)



Source: Baker Hughes, BofAML Global Research

Chart 24: Growth in horizontal drilling (b)



Source: Baker Hughes, BofAML Global Research

But there may be limits to the oil services sector's ability to expand these technologies while reducing unit costs to levels at which they can be more widely deployed globally.

Shale gas ex-US, growing interest

Worldwide production of shale gas is still small compared with conventional gas. Having seen the US fully embracing the resource and the technological side improving, we expect shale plays to attract increasing interest from other regions. We see both Europe and China moving in this direction. According to the latest EIA data, China has 1275 Tcf of shale gas resources, compared with 862 Tcf in the US and 639 Tcf in Europe as a whole.

Table 12: Estimated shale gas resources for select countries (vs existing reported reserves, production and consumption)

	2009 NG market(1) (tn ft ³ , dry basis)			Proved NG reserves (2) (tn ft ³)	Technically recoverable shale gas resources (tn ft ³)
	Production	Consumption	Imports (Exports)		
Europe					
Poland	0.21	0.58	64%	5.8	187
France	0.03	1.73	98%	0.2	180
Norway	3.65	0.16	-2156%	72	83
Ukraine	0.72	1.56	54%	39	42
Sweden	-	0.04	100%		41

Table 12: Estimated shale gas resources for select countries (vs existing reported reserves, production and consumption)

	2009 NG market(1) (tn ft ³ , dry basis)			Proved NG reserves (2) (tn ft ³)	Technically recoverable shale gas resources (tn ft ³)
	Production	Consumption	Imports (Exports)		
Others	6.2	10.55	NA	69.21	106
North America					
United States(4)	20.6	22.8	10%	272.5	862
Canada	5.63	3.01	-87%	62	388
Mexico	1.77	2.15	18%	12	681
Asia					
China	2.93	3.08	5%	107	1,275
India	1.43	1.87	24%	37.9	63
Pakistan	1.36	1.36	-	29.7	51
Australia					
Australia	1.67	1.09	-52%	110	396
Africa					
South Africa	0.07	0.19	63%	-	485
Libya	0.56	0.21	-165%	54.7	290
Algeria	2.88	1.02	-183%	159	231
Others	0.13	0.19	NA	3.4	36
South America					
Argentina	1.46	1.52	4%	13.4	774
Brazil	0.36	0.66	45%	12.9	226
Others	1.52	1.22	NA	212.9	225
Total of above areas	53.1	55	-3%	1,001	6,622
Total world	106.5	106.7	0%	6,609	

Source: EIA 1) Dry production and consumption: EIA, International Energy Statistics, as of March 8, 2011.; 2) Proved gas reserves: Oil and Gas Journal, Dec., 6, 2010, P. 46-49.; 3) Romania, Hungary, Bulgaria; 4) U.S. data are from various EIA sources.

China's shale gas reserves are estimated at 36tnm³ or 12x more fuel than its conventional fields – US EIA (April 2011)

China is looking to develop drilling technologies and in March 2011 completed its first horizontal shale gas well after 11 months of drilling, according to CNPC (vs as few as 16 days in the US)

China to become a key source of shale activity

China's rising energy needs mean it is increasingly looking to exploit its vast shale resources to help cover any deficit. It is currently drafting a five-year plan to 2015 to develop its reserves. National Energy Administration officials have said that the government may offer financial support and tax incentives to encourage domestic explorers, such as PetroChina, to extract shale gas. Longer term, China is looking to triple the use of natural gas to about 10% of its energy consumption by 2020 as it reduces its reliance on coal (80% of electricity today) and imported oil. Shale also offers an opportunity for China to reduce its reliance on carbon-intensive fuels in its energy mix – seeking a balance between growing energy demand and further deterioration of its natural environment.

Shell was the first of the majors to enter the shale plays in China in 2009, bringing with it technology to help the development of reserves. More recently, we have seen Chevron sign a deal to develop shale targets near Guiyang City. In return, many of the Chinese players are partnering in shale plays in the north of the US to develop the technical know-how and expertise which is largely found in the US and Europe. CNOOC has partnered with Chesapeake on Eagle Ford in the US, while PetroChina has partnered with Encana.

Oil services companies will also play a big role in developing this technical know-how. For example, Schlumberger recently won a contract to supply Sinopec with long-term service on well appraisals that covers both conventional and shale gas. With a lack of in-country knowledge, it seems likely that further long-term contracts will be signed with international oil services providers.

With good results Euro majors (BG, Eni, Total, Shell) could become more active. In our coverage, we see OMV and MOL as beneficiaries of progress in the CE European gas play. Outside our coverage, we believe Aurelian is the most levered name to this theme

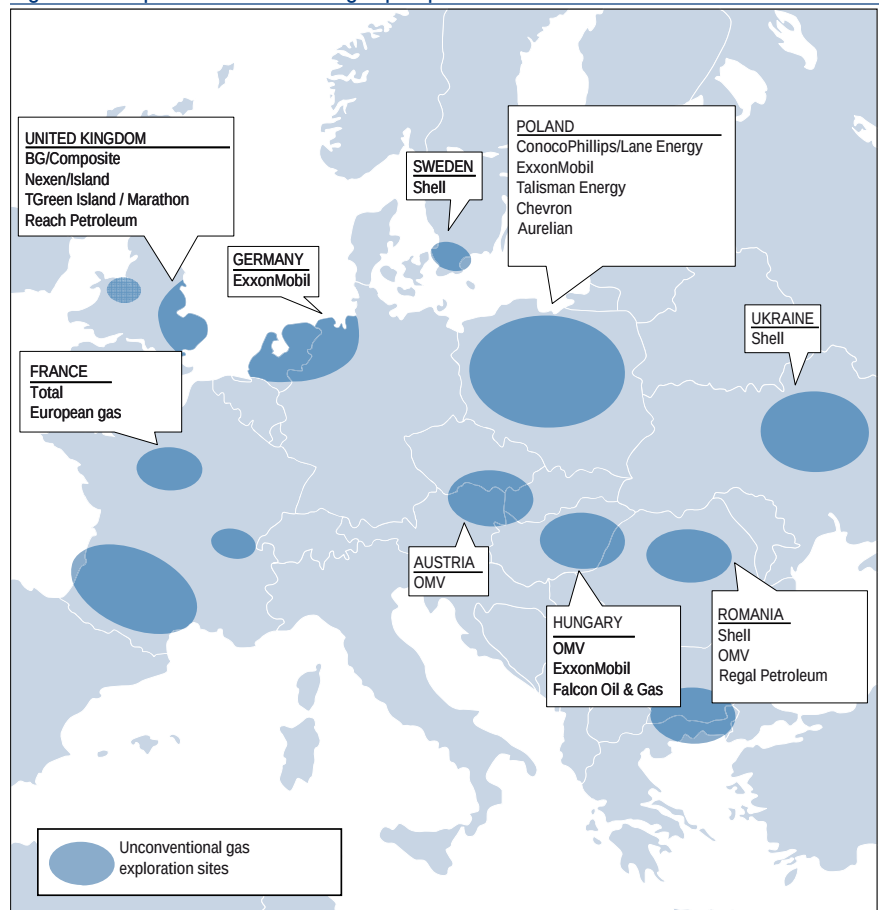
An emerging market in Europe

While reserves in Europe of c.640Tcf are well below those in the US and China, activity is rising, particularly in Poland. As conventional gas production declines in Europe, and as some countries grow uneasy about the high dependence on Russian imports and/or the prospects of a nuclear renaissance fade (ie, Germany, Italy), shale gas looks to be a plausible alternative:

- **Shale gas could meet the continent's energy needs for 30 years** according to a report by the consultancy firm McKinsey – commissioned by major gas giants including Gazprom, Centrica and others.
- **European leaders have agreed to assess the potential for sustainable extraction** of shale gas and oil shale and other unconventional fossil fuel resources. East European countries such as Poland are taking the lead, driven by energy security goals and the desire to seek alternatives to Russian gas.

However, some countries, such as France, are put off shale by the debate over the environmental implications (see further below).

Figure 3: European unconventional gas prospects



Source: Gas Matters, Woodmac, BofA Merrill Lynch Global Research

Poland at the forefront of shale gas

Shale gas has attracted more interest in Poland than anywhere else in Europe, with preliminary estimates suggesting that it could have between 1.4tcm and

5.3tcm of shale gas, with 86 unconventional concessions granted as of H1-11. There is growing interest from oil companies keen to participate. Poland has a number of features that make it attractive for shale:

- Its central location gives it good access to infrastructure, being the transport corridor between Russia and Western Europe.
- Low taxation has been encouraged, which helps to improve the economics of projects, with the government taking only 20% (19% tax, 1% royalty).
- Poland's power sector is dominated by coal (92%) and shale gas could provide a means of reducing GHG emissions and pollution, as well as improving security of supply.

But the industry will have to address several areas that are currently not widely understood – well depths may be much deeper than in the US, and productivity and recovery rates are unknown in the region.

Table 13: European unconventional gas plays

Country	Basin	Companies involved	Comments
Austria	Vienna basin	OMV	15 tcf of gas potential identified in deep Vienna basin, testing shale gas in 2009-10
France	Bresse basin, Lorraine basin, Nord pas-de-Calais, Paris basin, Southeast basin	Devon (DVN), East Paris Petroleum Development, European Gas Limited (EPGAU), Mouvoil SA, Bridgeoil Ltd, Diamoco Energy, Lundin Petroleum (LUPE), Toreador Resources (TRGL), Total (FP) EurEnergy Resources	Companies seeking permits in various basins
Germany	Lower Saxony basin, Bodensee Trough	ExxonMobil / WintershallRoyal, Dutch Shell (through partnership in BEBwith ExxonMobil), 3Legs Resources	XOM plans 10 wells on 750k acres 2009-10
Hungary	Bekes basin, Mako trough Penezlek	MOL / Exxon / Falcon Oil (FO) / Ascent Resources (AST LN)	Completed three disappointing hydraulic fracture tests within the Szolnok Formation on the Foldak-1 well
Netherlands	Central Graben, Vlieland, London-Brabant Massif, West Netherlands	Exxon / Shell / Cuadrilla Resources	Holds licences
Poland	Polish basin, Timan-Pechora Baltic-basin Suliran shale(shallowest 1-2km depth)	3Legs Resources, BNK Petroleum Inc. (BKX), ConocoPhillips (COP), Aurelian Oil & Gas (AUL), Talisman (TLM), San Leon Energy (SLE), 3Legs Resources Lane Energy / Sorigenia E&P, BNK Petroleum, EurEnergy Resources, RAG, RWE, Marathon Oil Corp, Chevron, Exxon Mobile	Preliminary data shows potential for shale gas. First well to be drilled May 2010. Will drill two horizontal appraisal well programs commencing June 2010 on Siekierki Gas field; seismic planned this year and TLM has committed to drilling three wells as part of a farm-in deal
Sweden	Alum shale Fennoscandian Border; Baltic Depression	Royal Dutch Shell	Owens licences, 3 year exploration project in Skane. Three well programs planned for 1Q 2010
Switzerland	Alpine Foreland basin		
Ukraine	Dnieper-Donets	Maraton, Naftogaz Ukrainy (NAK), JKC oil & Gas, (JKX), Regal Petroleum (RPT), Cadogan, Petroleum (CAD), Transeuro Energy (TSU)	MRO and NAK signed an agreement in June 07 to explore Dnieper-Donest basin. Other companies mentioned have interests in the basin or the vicinity
UK	Kincardine basin, Scotland (CBM) Cheshire basin, North west England	Composite Energy / BG, Island Gas (IGAS LN), Nexen (NXY CN), greenpark Energy, Marathon, AJ Lucas, Cuadrilla Resources, EurEnergy Resources,	3000ft depth, 40ft pay Total resources of 4tcf in Cheshire basin (WoodMac). First CBM production in June 2009 from IGAS Doe Green site

Source: Various news and company resources, BofA Merrill Lynch Global research

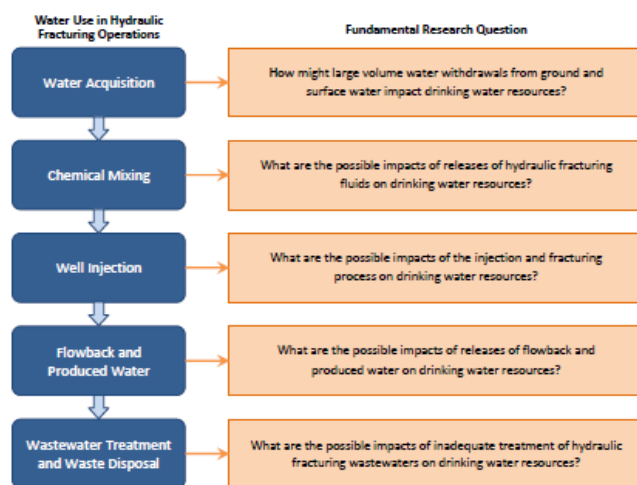
“Recognizing that access to available resources can be undermined by safety and environmental incidents, all industry participants must continually improve their environmental, safety, and health practices, preserving the benefits of greater access for the industry, consumers, and all other stakeholders” – U.S. National Petroleum Council

Fracking, HSE risks

Fracking is coming under growing scrutiny by stakeholders and regulators. The sector’s development, particularly in the US, has largely been one step ahead of regulations and oversight – with a patchy network of state-by-state or country-by-country requirements, restrictions, or frequent lack thereof across the globe. This has raised concerns – many of them not definitively proven or disproved – that shale gas poses potential HSE (health, safety and environmental) risks with regard to freshwater usage, injected water and wastewater and greenhouse emissions, among other areas.

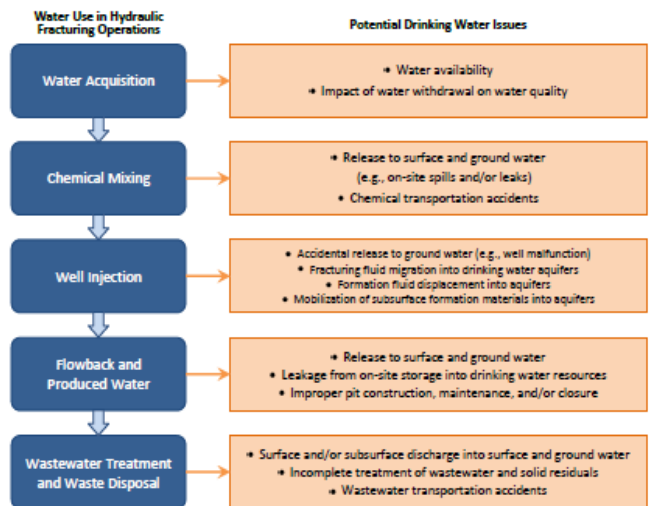
While we do not say that shale gas definitively poses such HSE risks, we believe that companies and investors need to adopt a prudent approach to shale gas development given the sometimes limited geotechnical understanding of the issues at play, especially outside the US. Some companies are conscious of this and we are starting to see cases of majors including protection clauses in M&A contracts that would allow them to walk away if new laws were to restrict fracking. If the sector is to achieve a long-term licence to operate globally, the industry must deal with the HSE impact of E&P, comply with existing regulations, proactively anticipate new regulations and ensure stakeholder buy-in.

Chart 25: Fundamental HSE questions need to be posed for each stage of the hydraulic fracturing water lifecycle



Source: US EPA

Chart 26: Potential drinking water issues relating to water use in hydraulic fracturing operations



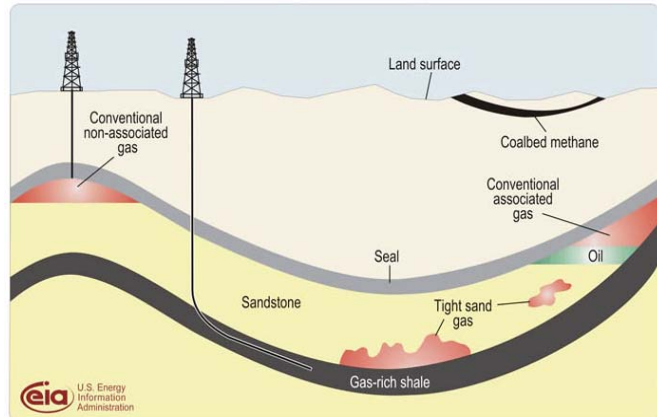
Source: US EPA

Hydraulic fracking and horizontal drilling have made the shale boom possible, but pose potential health, safety and environmental risks in terms of water contamination, fissures and clean-up

Growing HSE concerns over fracking

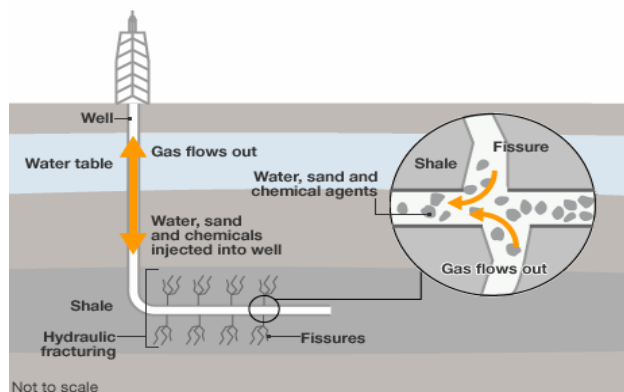
The US shale gas boom has, as discussed, been largely based on innovations in drilling techniques, which have allowed oil services companies to pioneer accessing gas from deep, dense shale rock formations. The key technique raising HSE concerns from stakeholders and regulators is hydraulic fracking – the process whereby water, chemicals and proppants (eg, sand) are pumped into the well to open fractures in the rock, allowing hydrocarbons to escape. While fracking has been used since the 1940s, the rapid and in some cases exponential application to shale gas in recent years has put regulatory frameworks to the test and raised HSE concerns.

Figure 4: Geology of natural gas resources



Source: EIA

Figure 5: Shale gas extraction incl. hydraulic fracturing



Source: Company data

Freshwater use, water scarcity & pricing

Shale gas involves large-volume water withdrawals from ground and surface water, which some believe could impact drinking water resources, create further water stress and scarcity, and force producers to look for new water sources.

Up to 80mn gallons per pad

The amount of water needed in the hydraulic fracturing process depends on the type of formation (eg, depth and porosity) and the fracturing operations (eg, well depth and length, fracturing fluid properties, and fracture job design). However, water use in shale gas plays is generally estimated at 2mn to 5mn gallons per well – although figures can in some cases be as high as 13mn (Source: EPA 2011). With companies drilling up to 16 wells per well pad, this amounts to an average of 32-64mn gallons – and up to a potential 80mn gallons of water per pad.

Table 14: Comparison of estimated water needs for hydraulic fracturing in different shale plays

Shale Play	Formation depth (ft)	Porosity (%)	Organic content (%)	Freshwater depth (ft)	Fracturing water (g/well)
Barnett	6,500-8,500	4-5	4.5	1,200	2,300,000
Fayetteville	1,000-7,000	2-8	4-10	500	2,900,000
Haynesville	10,500-13,500	8-9	0.5-4	400	2,700,000
Marcellus	4,000-8,500	10	3-12	850	3,800,000

Source: US EPA 2011

50,000 wells are fractured every year

We estimated that approximately 50,000 wells are fractured each year across the US. Assuming that the majority of these wells are horizontal, the annual water requirement could be 70-140bn gallons. This is equivalent to the total amount of water used each year in roughly 40 to 80 cities with populations of 50,000, or about 1-2 cities of 2.5mn people.

Need to keep water use in perspective

A typical US deep shale gas well will produce 2-6.5bcf over its lifetime. The amount of water used to produce the gas equates to about 0.8-1.7 gallons for every MMBTU. To put this in perspective, this is less than 20% of the water needed to produce one MMBTU of coal that is ready to burn in a power plant, or less than 0.1% of the water needed to produce the same energy equivalent of ethanol for fuel.

Table 15: Water requirements for various energy resources

Energy Resource	Gallons of water used per MMBTU of energy produced
Coal (no slurry transport)	2 – 8
Deep Shale Natural Gas	2.8 – 5.7*
Coal (with slurry transport)	13 – 32
Nuclear (uranium ready to use in a power plant)	8 – 14
Conventional Oil	8 – 20
Synfuel - Coal Gasification	11 – 26
Oil Shale	22 – 56
Tar Sands	27 – 68
Synfuel - Fisher Tropsch (from coal)	41 – 60
Enhanced Oil Recovery (EOR)	21 – 2,500
Biofuels (Irrigated Corn Ethanol, Irrigated Soy Biodiesel)	> 2,500

Source: Chesapeake Energy. * Includes 0-2 gallons per MMBTU for the transport of natural gas. MMBTU - one MMBTU equals about a thousand cubic feet of gas.

O&G companies' fracking wells are bidding up prices for water in certain regions

Water use is a material risk in some regions

In certain regions, such as Texas Eagle Ford Shale, a combination of drought and diversion of water to fracking has seen water prices increase to as much as US\$0.70 per 42-gallon barrel of water pumped from underground aquifers. The same water had no value only 3-5 years ago, pre-shale gas drilling. A study by the Texas Water Development Board and the University of Texas at Austin estimates that fracking water demand in the area could jump 10x by 2020 and double again by 2030. This is starting to raise concerns from stakeholders, such as farmers, who are facing increasing competition for scarce water resources. In other areas, concerns arise from flooding and the risk that drilling pits will overflow and spill their contents into flooded water sources.

Our WDW analysis shows water scarcity can be a risk

Given the potential water scarcity issues around shale gas, we have undertaken a geographic risk analysis of countries with major shale reserves. We have done this on the back of our *Who Does What Where* (WDWW - [SRI & Sustainability, 07 March 2011](#)) geographic risk-screening model – which ranks 205 countries across the water scarcity theme and the following indicators: annual freshwater withdrawals, internal freshwater resources, average temperature and precipitation. Applying this analysis, we can see that a number of countries looking to develop shale gas are facing critical water scarcity challenges.

Table 16: WDW Water Scarcity scores & ranks for countries

Country	Shale reserves (tcf)	WDWW score	Country rank /205
China	1,275	56.8	78
United States	862	49.7	109
Argentina	774	44.3	131
Mexico	681	40.4	146
South Africa	485	42.5	138
Australia	396	45.3	127
Canada	388	66.6	36
Libya	290	23.1	170
Algeria	231	32.6	160
Brazil	226	63.6	55
Poland	187	51.1	100
France	180	52.2	91
Norway	83	80.0	13
Chile	64	71.8	26
India	63	40.6	145

Source: BofA Merrill Lynch Global Research

We have undertaken a similar analysis for US states with major shale gas deposits and scored and ranked the countries according to their equivalent

country rank on WDW. The results are similar – water scarcity is clearly a challenge in a number of jurisdictions.

Table 17: WDW Water Scarcity scores & ranks for US states

U.S. State	Proven shale reserves (Bcf)	WDW score	Eq. country rank (205)
Texas	28,167	27.21	166
Louisiana	9,307	50.41	103
Arkansas	9,070	54.75	85
Oklahoma	6,389	55.97	81
Pennsylvania	3,790	62.67	58
Michigan	2,499	45.82	124
West Virginia	688	53.85	88
North Dakota	368	50.37	103

Source: BoFA Merrill Lynch Global Research

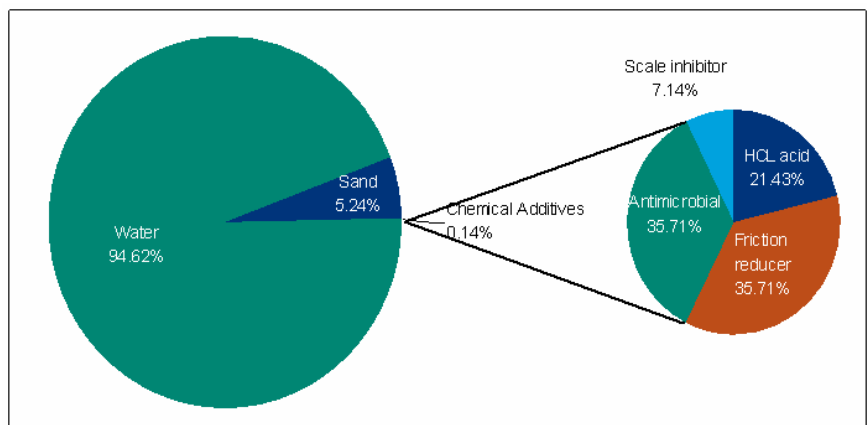
Injected water, chemical issues

Another potential concern is that chemicals are added to the water to facilitate the underground fracturing process – with notable issues arising with regard to the actual chemicals used in the fracking process as well as the lack of systematic disclosure requirements for the chemicals used (with a number of companies arguing that the information is proprietary).

Chemical use in fracking fluids

The overall concentration of chemical additives in fracturing fluids used in shale gas plays ranges from 0.5% to 2% by volume with water and proppant comprising the remainder. This indicates that 15,000 to 60,000 gallons of the total fracturing fluid consist of chemical additives (assuming a total fluid volume of 3mn gallons).

Chart 27: Composition of hydraulic fracturing fluid (by volume)



Source: GE

Table 18: Chemical components appearing most often in hydraulic fracturing products used in the US 2005-09

Chemical component	No. of products containing chemical
Methanol (Methyl alcohol)	342
Isopropanol (Isopropyl alcohol, Propan-2-ol)	274
Crystalline silica – quartz (SiO ₂)	207
Ethylene glycol monobutyl ether (2-butoxyethanol)	126
Ethylene glycol (1,2-ethanediol)	119
Hydrotreated light petroleum distillates	89
Sodium hydroxide (caustic acid)	80

Source: US House of Representatives

O&G service companies used fracking products containing 29 chemicals that are (1) known or possible human carcinogens, (2) regulated under the Safe Drinking Water Act (SDWA) for their risks to human health, or (3) listed as hazardous air pollutants under the Clean Air Act

Potential for water contamination

Fracking wells can use as much as 5mn+ gallons of water per well. Only about 50% to 70% of the resulting volume of contaminated water is recovered and stored in above-ground ponds pending removal by tanker. The remaining 'produced' water is left in the earth where it could potentially lead to contamination of groundwater aquifers. Additionally, if improperly handled, this fluid could harm surface water assets.

Deeper wells pose the greatest risk

Generally speaking, the fracs used in the shale gas industry in North America – where some shales are close to densely populated urban areas – use the simplest and least harmful fracking fluids. The greater risk, in our view, lies with the chemicals used in deeper reservoirs, where there is higher pressure and hotter temperatures. These chemicals are more viscous – some compare them to jelly – requiring greater chemical use to get them to that state.

Human health concerns over chemicals

The chemicals used also raise potential human health concerns. According to an April 2011 Congressional report, between 2005 and 2009, the US's 14 leading natural gas drilling service companies used hydraulic fracturing fluids containing 750 different chemicals and other components, including 29 chemicals that are known or possible human carcinogens or are federally regulated because at certain levels they are known to be quite harmful to human health. Two fracking products contained hydrofluoric acid, which can be fatal even in small concentrated doses or with minimal exposure. Many of the fracking fluids also contain chemical components that are listed as "proprietary" or "trade secret", so that stakeholders are not fully aware of what chemicals are being stored, used, or disposed of in their communities or near their drinking water sources.

Table 19: Chemical components of concern: Carcinogens, SDWA-Regulated Chemicals, and Hazardous Air Pollutants (HAP)

Chemical Component	Chemical Category	#	Chemical Component	Chemical Category	#
Methanol (Methyl alcohol)	HAP	342	Dimethyl formamide	HAP	5
Ethylene glycol (1,2-ethanediol)	HAP	119	Phenol	HAP	5
Diesel19	Carcinogen, SDWA, HAP	51	Benzene	Carcinogen, SDWA, HAP	3
Naphthalene	Carcinogen, HAP	44	Di (2-ethylhexyl) phthalate	Carcinogen, SDWA, HAP	3
Xylene	SDWA, HAP	44	Acrylamide	Carcinogen, SDWA, HAP	2
Hydrogen chloride (Hydrochloric acid)	HAP	42	Hydrogen fluoride (Hydrofluoric acid)	HAP	2
Toluene	SDWA, HAP	29	Phthalic anhydride	HAP	2
Ethylbenzene	SDWA, HAP	28	Acetaldehyde	Carcinogen, HAP	1
Diethanolamine (2,2-iminodiethanol)	HAP	14	Acetophenone	HAP	1
Formaldehyde	Carcinogen, HAP	12	Copper	SDWA	1
Sulfuric acid	Carcinogen	9	Ethylene oxide	Carcinogen, HAP	1
Thiourea	Carcinogen	9	Lead	Carcinogen, SDWA, HAP	1
Benzyl chloride	Carcinogen, HAP	8	Propylene oxide	Carcinogen, HAP	1
Cumene	HAP	6	p-Xylene	HAP	1
Nitrilotriacetic acid	Carcinogen	6			
No. products containing a component of concern					652

Source: US House of Representatives 2011

Casing is typically hollow steel pipe used to line the inside of the drilled hole (wellbore) and is essential for protection of groundwater and aquifers in a drilling operation

Cementing is the process of placing a cement sheath around casing strings

Stricter HSE regulation will make wastewater treatment risks a multi-billion-dollar opportunity

Casing & cementing are key to groundwater protection

Casing strings are an important element of groundwater protection because they provide for the isolation of fresh water zones and groundwater from the inside of the well. Casing also transmits flowback fluids from well treatment. Surface casing is the first line of defence and production casing is a second layer of protection for groundwater. Equally important is the cementation of the casing that adds huge value to groundwater protection. Proper sealing of annular spaces with cement creates a hydraulic barrier to both vertical and horizontal fluid migration. As a result, the quality of the initial cement job is a critical factor in the prevention of fluid movement from deeper zones into groundwater resources (Source: FracFocus).

Produced water, treatment risks & opportunities

While some efforts are being made to treat or contain the used fracking fluid, enforcement is currently not well developed. Moreover, the ways in which these chemicals are acting together with the sub-surface and potential leak into ground water is still not 100% understood or researched. In addition, recovered water may contain materials from the rock, such as naturally occurring radioactive materials and heavy metals. Greater regulation will mean a significant increase in wastewater treatment requirements and costs, which could rise by up to 300% in some areas.

Traditional treatment solutions are not viable

One concern is the possible lack of capacity by companies and relevant government authorities to clean up frac fluid-contaminated wastewater. This has been the subject of stakeholder scrutiny after a series of frack spills in the US, despite claims by many companies that the process is safe and time-tested. Existing solutions are coming under increasing stress.

Table 20: Concerns over traditional wastewater treatment of fracking fluid

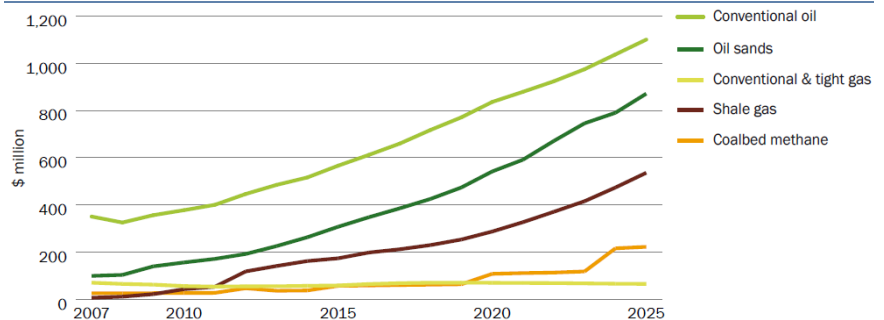
Treatment method	Concern
Dumping tainted water into ponds and rivers	Coming under increasing stakeholder attack and stringent regulation
Recycling wastewater for non-potable uses	A salty, contaminated sludge by-product can be used for de-icing roads or suppressing dust
Injecting it underground in "disposal wells"	Coming under increasing stakeholder attack and stringent regulation Not permitted in certain areas and/or the geological terrain (e.g. Marcellus shale) makes piping water over long distances unviable
Treatment by municipalities	Lack of appropriate equipment or capacity of many municipalities for additional treatment.
Fluid spill action plans	Lack of disclosure Lack of regulation enforcing spill response plans

Source: BofA Merrill Lynch Global Research

Water treatment, a multi-billion-dollar opportunity

The market for the wastewater treatment of shale gas wells could be worth tens of billions of dollars over the coming years. The billions of gallons of contaminated water should create significant long-term opportunities for companies involved in wastewater treatment solutions such as bag filters, combination, chemical precipitation, distillation, electric coagulation, membrane filtration, desalination and mobile treatment units (MTUs). Given the estimated life of shale plays, this market could reach US\$2-4bn per year in the coming years.

Chart 28: North America produced water equipment market 2007-2025



Source: GWI

Greenhouse gases, full life-cycle concerns

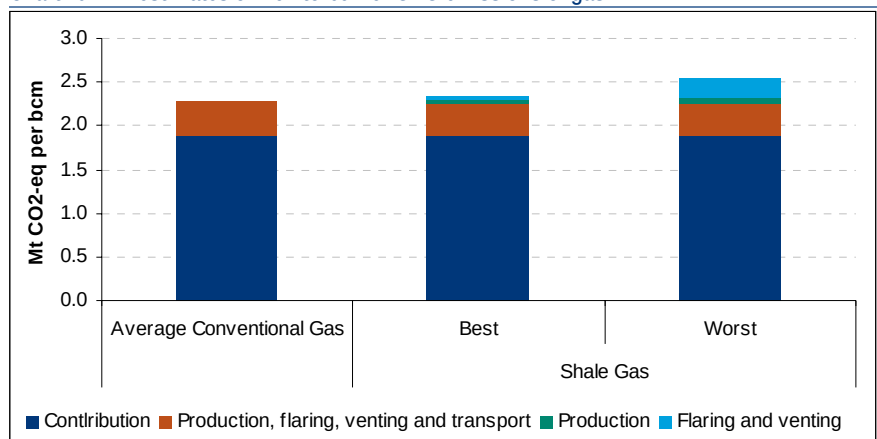
Shale gas is also coming under increasing scrutiny in terms of greenhouse gas (GHG) emissions. GHG from shale gas predominantly comprise: (1) CO₂ produced when the gas is burned, and (2) methane that leaks out while the well is being exploited. Molecule for molecule, methane is a much more potent GHG than CO₂, but it lasts for a much shorter time in the atmosphere. Many advocates of shale gas argue that it releases fewer emissions than other fossil fuels, like coal. However, this is open to debate with a growing body of evidence suggesting that shale gas could emit more full life-cycle GHGs than conventional NG, and potentially even coal or oil.

Higher “well to burner” emissions than conventional gas according to the IEA World Energy Outlook 2011

Full life-cycle, shale is worse than conventional gas

In June 2011, the IEA said that based on available data, shale gas produced to proper standards of environmental responsibility had higher “well to burner” emissions than conventional gas, with the combustion of gas being the dominant source of emissions.

Chart 29: IEA estimates of well-to-burner GHG emissions of gas



Source: IEA WEO 2011. The average value for conventional gas fugitive emissions was calculated using UNFCCC data. CH₄ emissions have been converted to a CO₂-eq basis assuming a global warming potential of 25 over a 100Y period.

With methane emissions, is shale worse than coal?

The GHG debate of shale gas vs coal largely centres on shale gas's methane emissions. Although it stays in the atmosphere for only a tenth as long as CO₂, methane has up to 105x greater global warming potential than CO₂ over a 20Y period, and 33x greater when viewed over a 100Y period (on a mass-to-mass comparative basis). It is still very early days – and much research needs to be done – but some of the major studies to date have shown the following mixed results:

- **The Council of Scientific Society Presidents calls for full life-cycle analysis** – in May 2009 the CSPP, an umbrella organisation that represents 1.4mn scientists, urged caution on developing shale gas without a better scientific basis for the policy. It noted that shale gas might actually aggravate global warming, rather than mitigate it. They suggested that any analysis of GHG emissions should encompass full life-cycle GHGs.
- **EIA says shale emissions are slightly higher than conventional gas**
According to June 2011 analysis by the EIA, the average emissions of shale gas (including activities specific to it) are 3.5% higher in the best case (flaring the gas) than the equivalent figure for conventional gas – and 12% higher in the worst case (venting the gas).
- **Cornell study says shale has a worse GHG footprint than coal or fuel oil** – the study published in April 2011 in Climatic Change Letters offers the first comprehensive analysis of the life-cycle GHG footprint of shale gas. It concluded that the GHG footprint of shale gas was significantly larger than that of conventional gas, due to methane emissions with flow-back fluids and from drill-out of wells during well completion – whereas routine production and downstream methane emissions are also large, but are the same for conventional and shale gas. The study concluded that shale's footprint is worse than those of coal and fuel oil when viewed for the integrated 20Y period after emission. On a 100Y integrated time frame, this analysis finds shale gas comparable to coal and worse than fuel oil.
- **A Carnegie Mellon study said a shift to shale could cut GHGs by 50%**
The August 2011 study focused on shale gas from the Marcellus formation and found that while current techniques do result in higher methane emissions than from conventional gas wells, the extra methane only increases life-cycle GHG emissions from well to burner tip by 3% on average. It argues that this is the case because the life-cycle emissions are dominated by combustion, which accounts for 74% of total emissions. As a result, when burned in a combined cycle power plant to generate electricity, shale gas results in emissions per kWh that are 20-50% lower than those from coal, depending on equipment and sources. The CMU team found shale gas and LNG roughly comparable, with both emitting around a quarter less CO2 equivalent per BTU than diesel fuel.
- **Worldwatch/Deutsche Bank finds NG beats coal by 47%** The study considered both top-down and bottom-up views of shale gas emissions. They found that the emissions from gas-fired power plants beat coal-fired plants by an average of 47%, even after taking into account higher EPA estimates for methane venting during gas production (and using the IPCC's 100-year global warming potential for methane of 25x).

Methane studies have come under attack

The high impact of methane studies have come in for some criticism from industry and some stakeholders for a number of reasons including incorrect assumptions about the quantity of methane leaked, the residence time of methane in the atmosphere and the GHG warming potential estimates used.

Blow-out safety concerns

In light of the GoM disaster, shale gas drilling has raised concerns about wells suffering blowouts – at drilling depths of 1-4 miles – and spilling thousands of gallons of fracking fluids into the surrounding environment, which could heighten concerns about the safety of fracking.

Much depends on green completion - companies' ability to prevent methane escaping into the atmosphere via venting, flaring or escaping from loose gas distribution pipe fittings

There has been only limited research into how fracking impacts biodiversity

“It is well-established that drilling like this can trigger small earthquakes.” –
British Geological Society

Biodiversity

Stakeholders are seeking assurances that shale gas drilling will not damage local biodiversity including forests, rivers, streams and wildlife. These include NGOs and new entrants such as The Sportsmen Alliance, which has 60,000 members in the states that overlay the Marcellus Shale. They are pushing for the creation of a publicly disclosed water quality database and best management practices.

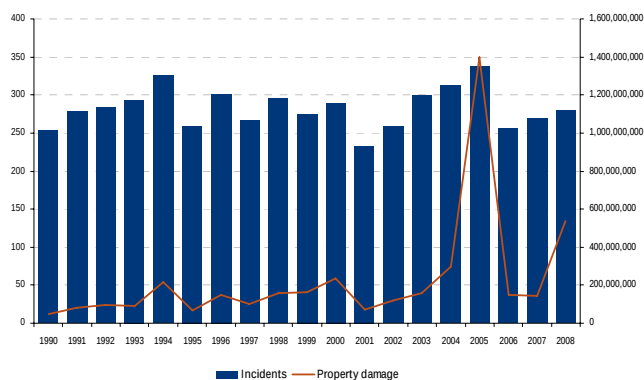
Fissures, faults & earthquakes

Some academics and industry experts argue that hydrofracking increases the risk of faults, fissures and earthquakes. Geologists have known of a possible link between fluid injection and small earthquakes for close to 50 years and the high-pressure injection of fluids used in fracking needs to be investigated further. Two earthquakes in a shale gas drilling zone in the UK in 2011 (2.3 magnitude) and 4.3 and 5.1 quakes in heavily drilled areas in the US have significantly upped stakeholder scrutiny and resulted in investigations.

Emerging pipeline debate

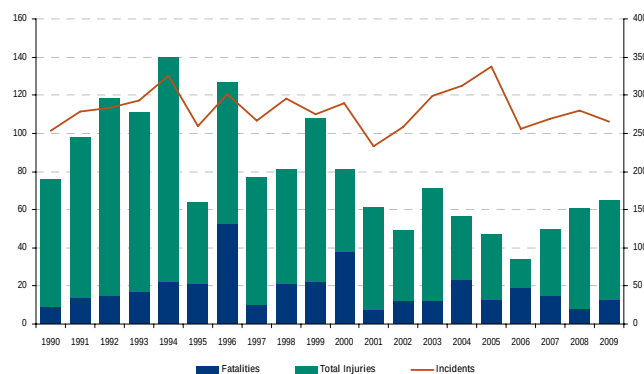
An emerging issue is stakeholder acceptance of pipelines to channel the gas to markets such as the northeast US. If stakeholder opinion turns against fracking, this could frustrate companies' efforts to obtain land rights, right of way and regulatory approvals for new pipelines and infrastructure. Most companies would be keen to avoid this as shale gas pipeline construction costs have already tripled from 2004-09 – now costing almost US\$200,000 per inch-mile for new projects and as much as US\$300k in the Marcellus region in Pennsylvania, according to a report by Ziff Energy Group, which reviewed new NG transportation infrastructure in the seven North American shale gas regions. We note, however, that the US Federal Energy Regulatory Commission can employ eminent domain to lay pipelines, if getting gas to market is deemed in the greater public interest.

Chart 30: US - All pipeline systems: incidents and property damage 1990-2009 (\$bn/year)



Source: US Department of Transportation PHMSA, BofA Merrill Lynch Global Research

Chart 31: US - All pipeline systems: significant incidents summary statistics: 1990-2009



Source: US Department of Transportation PHMSA, BofA Merrill Lynch Global Research

Greater scrutiny, costlier regulation

Shale gas has developed one step ahead of regulation

Shale gas has rapidly become a key element of energy policy. In the US, it has grown from only 1% of natural gas supply in 2001 to upwards of 20% today and is set to rise to as much as two-thirds by 2035. Other key markets outside the US are now looking to shale as a long-term solution. However, the regulators have had trouble keeping up, with shale gas's rapid development being criticised by stakeholders because of the lack of comprehensive, uniform or strict regulation. Shale gas is subject to a patchy network of state-by-state or country-by-country requirements, restrictions, or frequent lack thereof across the globe.

US and EU set to tighten regulation

A number of local jurisdictions, as well as France, have recently passed moratoriums or more stringent restrictions on fracking and shale gas drilling. We expect this process to continue in the US, which is likely to see much stricter regulation on the back of the Environmental Protection Agency's (EPA) ongoing investigation into shale gas due for 2012-14, and the recent decision of the Securities and Exchange Commission (SEC) to seek greater disclosure and subpoena companies. The European Commission is also looking to develop EU-wide rules on shale gas. We anticipate that other markets will follow the US and EU efforts and that we will see much stricter regulation on a 1-3 year time horizon.

Higher cost and tightened supply

At the very least, we expect to see much more in the way of regulation along the lines of recent decisions to require energy companies to disclose the chemicals used in the fracking process. We also anticipate regulations covering the treatment of the fluids used to drill a well, tighter restrictions on where companies get water, stricter standards for the casing that lines a well hole and a greater government role in water monitoring. While it is too early to estimate the cost of such regulation, producers can expect additional costs arising from red tape, increased drilling costs, delays in production, greener practices, greater disclosure, and potential litigation and regulatory risks associated with fracking. This could be margin make-or-break for higher-cost shale fields and could result in tightened shale gas supply.

US: stricter regulation by 2012-14

As things stand today, there is lack of comprehensive, uniform or strict regulation – with shale gas also subject to a number of exemptions from relevant environmental legislation:

- **Natural gas E+P falls under a range of regulators with competing agendas**, resulting in a lack of comprehensive industry oversight. Regulations vary across US states and different parts of the drilling process are subject to different state and federal regulations, including treatment and disposal of potentially contaminating tracking fluid, which is subject to varying federal regulations depending on whether it is above or below ground.
- **The US Federal Energy Policy Act (2005) exempts fluids – water and chemicals – used in natural gas extraction fracking** from the protections contained in the Clean Air Act, Clean Water Act, and the Safe Drinking Water Act (SDWA). This means that shale gas drillers do not have to disclose what chemicals they use. This decision was made after a 2004 EPA study which declared fracking safe, a move which was criticised by certain stakeholders

Shale gas is slipping through the cracks on US HSE regulations, either via competing agendas or exemptions

"We are encouraging the exploration of new frontiers of production and of new ways to safely make use of domestic assets like our vast reserves of natural gas." – Blueprint for a Secure Energy Future

as being politically motivated by pro-drilling advocates, arguing that the scope of the EPA's review was too narrow. But, as a result, shale gas drillers do not have to disclose what chemicals they use.

Feds support HSE-friendly shale gas development

The Obama administration in its March 2011 "Blueprint for a Secure Energy Future" opened the door to a supportive view on NG as an increasingly important source of US energy needs. The administration is taking several steps to proactively address concerns relating to shale gas development, such as:

- Tasking the Secretary of Energy Advisory Board (SEAB) with establishing a multi-stakeholder subcommittee to examine fracking issues;
- Identifying steps that can be taken to improve the safety and environmental performance of fracking; and
- Developing consensus-recommended advice to the agencies on practices for shale extraction to ensure the protection of public health and the environment.

In addition to the Blueprint, the federal administration is calling on industry to be more transparent about the use of fracking chemicals, particularly on federal lands.

Supporters of NG also introduced a bipartisan bill in April 2011 to encourage natural gas use, the New Alternative Transportation to Give Americans Solutions (NAT GAS) Act.

EPA is targeting pollution from shale gas

In April 2011, the EPA targeted pollution from gas drilling, particularly fracking. The proposed regulations are designed to eliminate most releases of smog- and soot-forming pollutants from these wells. New controls on storage tanks, transmission pipelines and other equipment – at both oil and gas drilling sites on land – would reduce by a quarter the amounts of cancer-causing air pollution and methane, the main ingredient in natural gas, but also one of the most powerful contributors to global warming. The rules could even save companies money as they could sell the gas they are forced to collect.

FRAC Act could amend safe water exemptions

There has been pressure to repeal the 2005 regulatory exemption under the Energy Policy Act of 2005 and in June 2009 two identical bills named the "FRAC Act" (Fracturing Responsibility and Awareness of Chemicals Act) were introduced to both the US House and the Senate. These bills are designed to amend the Safe Drinking Water Act and would eliminate fracking's current exemption. This would allow the EPA to reclassify producing wells as injection wells, placing them under federal jurisdiction in states without approved UIC (Underground Injection Control) programs. The bills would also require the energy industry to disclose what chemicals are being used.

Many cities and states have already acted

Several North American cities, states and provinces have begun to take action on fracking including Buffalo, Colorado, Maryland, New York City and State, Ohio, Pennsylvania, Pittsburgh, Quebec, Texas, West Virginia and Wyoming, among others. The measures undertaken have ranged from fracking impact studies to disclosure of fracking chemicals to outright bans or moratoriums on fracking.

State by state regulation overview
(<http://FracFocus.org/regulations-state>)

"Our research will be designed to answer questions about the potential impact of hydraulic fracturing on human health and the environment... The study will be conducted through a transparent, peer-reviewed process, with significant stakeholder input." - Paul Anastas, Assistant Administrator for EPA's Office of Research and Development

Industry had been urging the EPA to keep the study narrowly focused

Many local jurisdictions are also looking for compensation in the form of taxes or impact or severance fees for extracting or "severing" NG from where drilling takes place, in order to offset local infrastructure and/or environmental costs.

EPA study 2012-14 will set tone for global HSE debate

Congress has also asked the US EPA to study the safety of fracking technology and the potential dangers to groundwater. The purpose of the EPA study is to examine the effects of fracking on the water supply, specifically for human consumption. The research aims to examine the full scope of the water pathway as it moves through the hydraulic fracturing process, including water that is used for the construction of the wells, the fracturing mixture, and subsequent removal and disposal. In June 2011, the Scientific Advisory Board identified seven sites for investigation. EPA investigators will study places where fracking has already taken place and look for any impact on residential water wells and other sources of drinking water. Another part of the study involves monitoring the fracking process throughout the life cycle of a well. Initial research should be completed by the end of 2012, and the EPA's Hydraulic Fracturing Report is expected to be completed in 2014.

Study will clarify the HSE debate

The study is likely to go some way towards clarifying some of the HSE issues around shale oil for the US market. The EPA recently said that because fracking occurs thousands of feet below the surface, there is a certain level of protection against contamination of groundwater. Nonetheless, the EPA addressed the volume of water used in fracking and said it would evaluate the integrity of some individual wells as part of a high-profile study. The EPA claims that the section that would be amended in the Safe Drinking Water Act is flexible, in that it defers the regulation of fracturing and drilling to the state. The EPA also says that since most states currently have regulations on fracturing, they would most likely agree with the state's policy and there would not be much change.

SEC investigation, increased scrutiny of operations

Oil & gas companies involved in shale operations, and oilfield services companies providing fracking services can expect increased scrutiny from the US Securities and Exchange Commission (SEC). The SEC is seeking greater disclosure from companies and has also issued subpoenas, indicating that a more formal investigation is under way. While it is still early days, the effects could be significant, especially given that the potential risks associated with fracking affect almost all O&G development companies (which use fracking with conventional wells, generally using lower injection volumes).

Staff comments on filings seeking greater disclosure

The SEC's Division of Corporation Finance issued comment letters over the summer of 2011 seeking detailed disclosures regarding hydraulic fracturing and shale industry risks and the amount and specific nature of the hydraulic fracturing chemicals used.

Table 21: SEC staff comments seeking shale disclosure

Factor	Disclosure
Hydraulic Fracturing Activities	•Location of hydraulic fracturing activities; •Acreage subject to hydraulic fracturing activities; •Percentage of reserves subject to hydraulic fracturing activities; •Percentage of services involved in hydraulic fracturing; •Anticipated costs and funding, including any capital expenditures, associated with the hydraulic fracturing activities; •Any incidents, citations or suits related to hydraulic fracturing activities for environmental concerns, including the circumstances, any penalties and the response to these matters;

Table 21: SEC staff comments seeking shale disclosure

Factor	Disclosure
Steps taken to minimize any potential environmental impact of hydraulic fracturing activities	•Established steps to ensure that drilling, casing and cementing adhere to known best practices; •Real time monitoring of the rate and pressure of the fracturing treatment for any abrupt rate or pressure change; •Evaluation of the environmental impact of additives to the fracturing fluid; •Any effort to minimize the use of water and/or dispose of it in a way that minimizes the impact to nearby surface water; and •Any established remediation plans or procedures to deal with the environmental impact that would occur in the event of a spill or leak;
Consequences of the loss of hydrocarbon containment during drilling	•Consequences
All material information regarding potential liability in connection with an environmental contamination related to hydraulic fracturing activities	•Applicable policy limits related to insurance coverage; •Related indemnification obligations and those of customers, if applicable; •Insurance coverage with respect to any liability related to any resulting negative environmental effects; and •Insured risks for the hydraulic fracturing activities; and •Report (provided to the Staff supplementally) detailing for representative wells in each of the material resource plays where the company operates all chemicals used in the hydraulic fracturing fluid formulation/mixture, the volume/concentration of the chemicals and total amounts utilized.

Source: Company disclosures, BofA Merrill Lynch Global disclosure

Subpoenas: a more formal investigation could be under way

The SEC has also issued subpoenas to certain shale producers requesting information pertaining to proved reserve estimates from shale gas wells and the actual productivity of producing shale wells. A number of companies have disclosed receipt of the subpoenas from the SEC, revealing that they request information pertaining to proved developed producing shale gas wells, reserve estimates and well economics. The SEC apparently stated that its investigation is a fact-finding inquiry and noted that the investigation arose out of recent media reports questioning the projected decline curves and economics of shale gas wells.

Europe: regulation before large-scale drilling

To date, there has not been any significant regulation on shale gas in the EU, except for an indirect mention in the Second Strategic Energy Review. The situation is complicated by the fact that EU petroleum legislation makes no clear mention of unconventional gas, which means it is not at all clear how the industry will be regulated and on what basis. However, given the current tenor of the debate with stakeholders and the European Commission's track record in terms of regulating new HSE issues, we see a growing likelihood that the EC itself – as well as many EU member states – will look to create a stringent regulatory framework before shale gas drilling and operations begin.

Energy Commissioner favours EU-wide rules

Brussels intends to draft EU-wide rules on shale gas reserves, according to September 2011 comments by Energy Commissioner Guenther Oettinger. Mr Oettinger said that he was seeking environmental protection standards that enable member states to grant licences within a clear framework – which he felt were best achieved by European common standards. He suggested that the Commission put proposals to member states as early as spring 2012.

EU parliament looking to an Energy Quality Directive

A highly influential member of the European parliament – German Social Democrat MEP Jo Leinen, who chairs the EU parliament's main body overseeing environmental regulation – has proposed a new directive that would penalise or even ban the exploitation of shale gas. There are no details as to what such an "energy quality" directive would look like, but, based on other examples, it could impose effective limits or financial penalties on shale gas use, depending on the HSE consequences. Leinen has the power to bring forward proposals that could make it into law within a few years.

"We need to be looking much more carefully at shale gas, and at the consequences of pursuing it" Jo Leinen, June 2011

Industry is likely to be strongly opposed

Plans for a Directive on energy quality are likely to be resisted by the O&G industry, which is lobbying for shale gas to be accepted as a "green" alternative to fossil fuels and even renewables. For instance, a European Gas Advocacy Forum has been pushing the argument that gas could deliver GHG savings at lower cost than adopting renewables.

Debate could be influenced by Poland, which has EU leadership for H211

The EU shale gas debate could, however, be influenced in the short term by Poland having taken over the rotating EU presidency for H2 11 for the first time. Poland is one of the EU's strongest shale gas advocates – and has argued that shale development could be crucial to EU energy security, especially in the wake of stalled nuclear development. As such, it is likely to be staunchly opposed to EU-level regulation of the nascent EU shale gas sector. We note that stakeholders have expressed some concerns over the lack of reference to climate change in Poland's EU presidency programme. Poland recently blocked proposals to toughen the EU's CO2 emissions target from 20% to 25% in 2020 (vs. 1990 levels), largely because of its dependence on coal.

Increasing debate and action at country level

At individual country level, we are seeing a vigorous dialogue and debate on shale gas with views ranging from the imposition of a complete ban on fracking in France to a pro-active push for development in Poland, along with everything in between. As shale gas attracts increased mainstream coverage, we are also seeing a ratcheting-up of stakeholder scrutiny with local communities, NGOs and political parties all taking views.

China: looking to spur development

China, which has some of the world's largest shale gas deposits, is drafting a five-year plan to 2015 to develop its reserves. National Energy Administration officials have said that the government may offer financial support and tax incentives to encourage domestic explorers, such as PetroChina, to extract shale gas and to help China reduce its reliance on coal and imported oil.

Early days on HSE

Given the relative newness of fracking in China, the Ministry of Environmental Protection has yet to comprehensively study the potential environmental impact of shale gas. To date, the Ministry of Environmental Protection's Pollution Control Department has examined only environmental impacts at shallow depths. This could become a regulatory and cost issue, as the gas in some of China's key deposits (eg, Sichuan and Tarim basins) is found at depths of 2-4 miles, rather than 1-2 miles in the US, and the Tarim basin is in an arid desert region, posing challenges for already strained groundwater resources.

Cost impact of greater regulations

It is too early to estimate the potential cost burden of regulation as we do not yet know the full extent of what will be regulated. However, likely (if not certain) additional cost burdens across a number of areas include:

- Additional red tape
- Lengthier process for receiving drilling permits
- Increased drilling costs (eg, changing the well casing from steel to concrete)

- Delays in production
- Tightened NG supply
- Potential litigation and regulatory risks associated with fracking

Industry's positioning

Industry is, as one might expect, warning of the dangers of increased HSE regulation. For instance, according to research conducted by the industry trade group Independent Petroleum Association of America, regulations such as the US FRAC Act, if passed, could:

- Add nearly US\$100,000 - US\$150,000 in costs to each well.
- Remove nearly 245bcf of supply each year, representing 5% of the existing shale gas production.
- Force 57% of domestic oil and 35% of domestic gas wells to cease production, costing the federal government US\$4bn in revenue, while state treasuries would lose out on US\$785mn in state severance and income taxes.
- Cut domestic energy production by 183,000bpd and 245bcf of natural gas every year.

Industry must engage with stakeholders

If it is to maintain its licence to operate, industry needs to be pro-active and stay one step ahead the regulator, adopting such best practice measures as: safeguarding the quality and quantity of regional surface and groundwater resources through sound wellbore construction practices; sourcing fresh-water alternatives and recycling water for reuse as far as is practicably possible; measuring and disclosing water to reduce the environmental impact; supporting the development of fracturing fluid additives with the least environmental risks; and supporting the disclosure of fracturing fluid additives.

Traditional position is no longer tenable

In addition to arguing the energy security, job creation and economic development potential of shale gas, the O&G industry has largely argued that fracking is relatively safe, pointing out that:

- Fracking has been used commercially for 60+ years;
- There have been no instances of contaminated drinking water in that time;
- Fracking takes place at depths of up to 10,000 feet (vs water supplies which are generally 500 feet below ground); and
- It has been said to be so by the US EPA, the Groundwater Protection Council and the Interstate Oil and Gas Compact Commission.

Arguments that current regulation is sufficient

Industry bodies, such as the Independent Petroleum Association of America, have said that they believe that states already sufficiently regulate fracking and that they see potential changes such as the FRAC Act as an additional layer of regulation that is unnecessary and cumbersome. They have also been uneasy about measures which would force them to disclose the chemical constituents

and formulas used in the fracking process, arguing that such information is a trade secret. Some industry lobbies have gone further, with Energy in Depth saying that the new regulations could cause US domestic gas production to drop by 245bcf/year, along with US\$4bn in lost revenue to the federal government.

Adopting a stakeholder-friendly approach makes business sense

More recently, industry appears to be taking on board concerns raised by stakeholders and regulators, saying that the benefits of shale gas need to be balanced against environmentally responsible development. We saw this with the September 2011 communiqué of the National Petroleum Council (NPC), which stated that in order to realize the benefits of these larger natural gas and oil resources:

- **Safe, responsible, and environmentally acceptable production and delivery** must be ensured in all circumstances.
- **Resource development must include effective regulation** and a commitment from industry and regulators to continually improving practices to eliminate or minimize environmental risk. These steps are necessary for public trust.
- **Access to available resources must not be undermined by safety and environmental incidents**, so all industry participants must continually improve their environmental, safety, and health practices, preserving the benefits of greater access for the industry, consumers, and all other stakeholders.

Moving to HSE best practice on shale gas

In the absence of well-formulated regulations in the US or globally, companies need to pro-actively apply a combination of best practice standards, operational competence & development and new technologies. This is likely to increase costs, but in the long term it should ensure that a licence is gained to operate and that gas is available for sale, thus increasing revenues.

Voluntary disclosure on chemicals

In the first instance, companies can go some way towards assuaging stakeholder concerns by voluntarily disclosing the chemicals they use. The most important initiative in this regard is the www.FracFocus.org website, a US registry where companies disclose the chemical additives used in the hydraulic fracturing process. The website was launched by the Ground Water Protection Council (GWPC) and the Interstate Oil and Gas Compact Commission (IOGCC), with funding from the Department of Energy.

- The website will show chemical additives used in the hydraulic fracturing process on a well-by-well basis, for wells drilled starting in 2011.
- Participating energy companies voluntarily upload information on the website about the chemical additives and the proportion used in each hydraulic fracturing job, using a standard template.
- The website gives stakeholders public access to comprehensive information about wells nationwide. Search fields allow users to identify wells by location, operator, state, county and well identification (API) number.

The IOGCC represents the governors of more than 30 O&G producing states, with a mission to conserve domestic resources while ensuring environmental protection

The GWPC comprises state water and underground injection control agencies, with a mission to protect and conserve groundwater

- BP, ConocoPhillips, ExxonMobil, Shell and 49 other natural gas companies are participating in the initiative. In its first two months of operation, participating companies uploaded more than 1,000 wells into the disclosure registry.
- Several state regulators allow operators to meet state reporting requirements by submitting chemical information through FracFocus (ie, Montana, Texas).

Table 22: 54 companies participating in FracFocus (as of August 2011)

Anadarko Petroleum Corporation	Encana Oil & Gas (USA)	Occidental Oil and Gas
Antero Resources	Energen Resources Corp	PDC Energy
Apache Corporation	Energy Corporation of America	Petrohawk Energy Corporation
BP America Production Company	EnerVest, Ltd	Pioneer Natural Resources
BHP Billiton Petroleum (Fayetteville)	EOG Resources	Plains E&P
Bill Barrett Corporation	EQT Production	Prima Exploration
Cabot Oil & Gas Corporation	EXCO Resources (JV w/ BG)	QEP Resources, Inc.
Chesapeake Energy Corporation	Forest Oil Corp	Range Resource Corporation
Chevron USA	Gunnison Energy Corp	Samson
Chief Oil & Gas LLC	Hess Corp	SandRidge energy
ConocoPhillips Company	High Mountain E&P	Seneca Resources Corporation
Devon Energy	HRM Resources	Shell E&P
Chief Oil & Gas LLC	J-W Operating Company	SM Energy
Citrus Energy	Laredo Petroleum	Southwestern Energy Production
ConocoPhillips Company	Marathon Oil Corporation	Talisman Energy USA Incorporated
CONSOL Energy	Mesa-Energy Partners	Ward Petroleum
Devon Energy	Newfield Exploration Company	Williams
El Paso E&P Company	Noble Energy	XTO Energy / ExxonMobil

Source: FracFocus

Supply chain factor at play

There is also a supply chain element at play, with companies able to encourage their fracking service providers to use lower-impact chemistries for additives such as friction reducers and surfactants, while keeping in mind both functionality and cost-effectiveness.

Minimising water use & treating wastewater

Companies can take a number of measures to reduce the burden on water resources and water and wastewater treatment and disposal needs – notably: reducing the amount of fresh water needed to conduct fracking operations; reusing and recycling water; and reducing the amount of water that is treated and discharged to treatment plants or discharge facilities:

- Using non-potable water where possible (ie, unsuitable for drinking, livestock or irrigation).
- Ensuring gas wells and geological formations (ie, freshwater aquifers) remain hydraulically isolated in the design, well construction and long-term production process during the life of the well.
- Storing all flowback and produced water in specially designated steel tanks before recycling.
- Recycling water using filtering technology.
- Using recycled water from previously fracked wells on subsequent completions.

- Treating water to remove hydrocarbons, chemicals and solids or reduce them to low levels before discharge.
- Permanently storing water that cannot be recycled in deep underground aquifers (underground injection control wells).
- Targeting a recycling rate of 100% of frac fluid, resulting in zero discharge.
- Testing groundwater before and after drilling to determine whether changes have occurred as a result of activity.
- Minimising the use of harmful chemicals and looking for green(er) alternatives.

Table 23: Technologies for treating contaminated water

Technology	How they work	Pros	Cons
Bag Filters	Sand and grit is trapped in a filter, while the rest of the water comes through	Cheap	Leaves all the other pollutants in the water
Combination	Oxygen molecules change the composition of pollutants, making them less harmful	Almost no waste is created; destroys bacteria	Does not remove salt
Chemical Precipitation	Chemicals are added into water; the chemicals precipitate metals into form, and the metals are then removed	Widely used; relatively cheap	Does not remove salt; generates a sludge requiring disposal
Distillation	Uses heat to evaporate fresh water	Only method that removes salts from waters with high concentration of solids	More expensive as it has high energy input and may require pretreatment to remove metals
Electric Coagulation	Charged particles attach to metals and separate them from water; the pollutants are then skimmed off	Avoids the use of chemicals for treating water	Does not remove salt; not widely used for large scale applications; generates a sludge requiring disposal
Membrane Filtration	A nano filter is used to remove metals	Can effectively reduce metals and to some degree salts; requires little or no pre-treatment	Filter media may need to be replaced frequently, raising costs

Source: WSJ, Penn State Marcellus Center for Outreach and Research, press sources

Preventing spills

In addition to traditional spill and emergency response plans, companies can take a number of measures to reduce the risk of spills and/or contamination of groundwater:

- Keeping well construction and producing activity a certain distance (eg, 1,500 feet or 457m) from surface water bodies with the same watershed.
- Cementing solutions that constitute a lasting barrier between the annulus and the formation and evaluating the integrity of this barrier long after the well is drilled and stimulated.
- Lining wells with multiple layers of corrosion-resistant steel and sealing off wells with cement from surrounding rocks to prevent leaks and freshwater aquifers.
- Lining all surfaces around drilling and fracking operations with plastic liners to contain spills and prevent fluids coming into contact with groundwater.
- Cementing casing at the uppermost portion of the well to protect groundwater; multiple strings of casing to ensure groundwater protection; and as the well is dug deeper, additional cement and casing to isolate NG-producing formations from groundwater

- Storing all completion fluid and flowback/formation water in lined tanks; and placing special protective barriers on the well pad under lined storage tanks and where trucks deliver fluids.

Ideal cementing solutions will be able to withstand higher wellbore pressures due to stimulation and be able to “self heal”, or automatically close cracks in the cement sheath when exposed to hydrocarbons.

Limiting gas venting

Fracturing fluids which return from the well with the gas can be separated from the gas in temporary facilities during the completion phase. Separated gas can be fed into a gathering system so that it can be used. Flaring is preferable to venting if the gas cannot be used.

Engaging with stakeholders, transparency is key

Shale gas companies must be committed to stakeholder engagement, notably via transparency so that the general public and interested groups have the information necessary to understand the challenges, risks and benefits associated with shale gas. This is an essential part of earning and maintaining public trust and critical to establishing appropriate public policies and regulations. They also need to work with communities to seek ways to reduce the tangible or perceived negative impacts of development (eg, predevelopment planning, alternative views, etc). FracFocus is a positive example in this regard.

Investors are expecting action

One reason companies need to act is that a growing body of asset owners and asset managers are engaging and targeting companies on shale gas-related HSE risks. 2010 and 2011 have seen a huge increase in shareholder resolutions at O&G companies' AGMs on shale gas-related issues, which have achieved significant levels of support at major multinational companies and/or been withdrawn after changes in company practices. The proposals have been supported by up to several dozen investors as well as CERES (a coalition of investors and environmental groups that works with companies to improve their business practices) and broadly propose that companies:

- Disclose their policies for reducing environmental and financial risks from the use of chemicals
- Tackle water impacts and other environmental issues associated with fracking
- Start recycling and reusing waste waters, reduce the volume and toxicity of chemicals
- Ensure the integrity of well cementing by using pressure testing and other methods
- Estimate and disclose the potential litigation and regulatory risks associated with hydraulic fracturing.

“The risks associated with unconventional shale gas extraction have the potential to negatively affect shareholder value. I urge companies working in this field to share their risk mitigation and management strategies with investors and the public.” - New York State Comptroller Thomas DiNapoli

Table 24: Outcome of shareholder resolutions on shale gas

Company	Outcome	Resolution filer	Year
Anadarko Petroleum Corporation	Withdrawn in response to corporate commitments	Trillium Asset Management	2011
Cabot Oil & Gas Corporation	Withdrawn in response to corporate commitments	New York State Common Retirement Fund	2011
Cabot Oil and Gas	Vote: 36%	New York State Common Retirement Fund	2010
Carrizo Oil & Gas	Vote: 44%	New York State Common Retirement Fund	2011

Table 24: Outcome of shareholder resolutions on shale gas

Company	Outcome	Resolution filer	Year
Chesapeake Energy Corporation	Vote: 25%	New York State Common Retirement Fund, Green Century Capital Management	2010
Chevron	Vote: 41%	Sisters of St. Francis of Philadelphia	2011
El Paso Corporation	Withdrawn in response to corporate commitments	Miller/Howard Investments	2010
El Paso Corporation	Withdrawn in response to corporate commitments	Miller/Howard Investments	2011
Energen Corporation	Withdrawn; procedural grounds	Miller/Howard Investments	2010
Energen Corporation	Vote: 49.5%	Miller/Howard Investments	2011
EOG Resources	Vote: 31%	Green Century Capital Management	2010
EQT Corporation	Omitted, per SEC, on procedural grounds	Miller/Howard Investments	2010
Exxon Mobil	Vote: 26%	Park Foundation (via As You Sow)	2010
Exxon Mobil	Vote: 28.2%	Park Foundation (via As You Sow)	2011
Hess Corporation	Withdrawn in response to corporate commitments	New York State Common Retirement Fund	2010
Range Resources	Withdrawn in response to corporate commitments	New York State Common Retirement Fund	2010
Southwestern Energy	Withdrawn in response to corporate commitments	Domini Social Investments	2011
Ultra Petroleum	Vote: 21%	Green Century Capital Management, As You Sow Foundation	2010
Ultra Petroleum	Vote: 42%	As You Sow	2011
Williams Companies	Vote: 42%	Green Century Capital Management	2010
XTO Energy, Inc.	Company in merger agreement with ExxonMobil	New York State Common Retirement Fund	2010

Source: Company disclosure, press sources

Appendix 1 - O&G company actions to reduce HSE impacts of fracking

Table 25: Overview of selective actions taken by companies to reduce HSE-related risks for shale gas

	Water use	Chemicals	Spills	Other
Anadarko	-Uses 3-5mn gallons of water to frack wells; utilise fresh water sources & all are permitted and regulated -In Pennsylvania, it stores all flowback & produced water in specially designated steel tanks; recycles almost all of the water utilising filtering technology; the recycled water is then used on subsequent completions, significantly reducing fresh water consumption. In some places it utilises disposal wells where the produced water is pumped into reservoirs 1 mile+ underground	-Participant in FracFocus*	-Developed Spill Prevention Guidelines: focus on reducing the potential for spills by enhancing awareness during specific activities. Daily prevention discussions are held on all job locations; site-supervisor approval is required prior to fluid transfer operations; All fluid transfers monitored by an employee or designated contractor; 3rd-party spill response personnel are on site and available 24 hours a day	-Goal is to create as much, if not more, marsh than was lost through a range of strategies, from planting grasses to hold the soil to routing pipelines through open water rather than disturbing marsh
Apache	-Relies on non-potable water in its operations -In mature oil fields (e.g. Permian Basin), salt water is separated from the oil and frequently pumped right back into the reservoir, enhancing recovery & minimising the disposal of production by-products	-Participant in FracFocus*	-Wells are lined with corrosion-resistant steel and sealed off from the surrounding rocks by cement to prevent leaks.	-Leader in enhanced oil recovery (EOR) and carbon capture and storage (CCS) technology -To protect drinking water aquifers close to the surface, wells are lined with corrosion-resistant steel and sealed off from the surrounding rocks by cement to prevent leaks
BP	-Treatment plants to remove hydrocarbons, chemicals & solids down to very low levels before the produced water or waste water is discharged. -Water that cannot be recycled will be disposed of in deep underground aquifers for permanent storage, and replaced by water from non-potable underground aquifers.	-Reports on its discharges to water in terms of drilling muds and chemicals, oil and chemicals in produced water (exploration and production), and chemical oxygen demand in waste water (all other businesses).	-Continues to develop and assimilate lessons from the response effort, which they plan to incorporate into group-wide mandated practices specifically on oil spill preparedness and response.	-In the thermal desorption facility, the OBM (Oil Based Mud) drill cuttings are heated to high temperatures, allowing for separation and recovery of 99.5% of the oil and gas for reuse. -Facility also recovers water, which is of high enough quality to be used for irrigation to create or sustain green areas in the desert. This reduces the need for water desalination or importation. The remaining treated solids produced by the unit are converted, on location, into interlocking bricks, which are used for the building of pavements and walkways in rural villages.
Cabot O&G	-Recycles and reuses 100% of returned frac fluid in Pennsylvania. When fresh frac fluids are required, it mixes the fresh water, sand and additives onsite. it uses this approach to limit the need to truck large quantities of treated fluids to production sites.	-Participant in FracFocus* -Does not store frac fluids or flowback fluids in open pits; all frac fluids and flowback fluids used by the company are stored in closed containers. -Encourages its fracking service providers to use lower impact chemistries for additives such as friction reducers and surfactants, while keeping in mind both functionality and cost effectiveness.	-Casing is cemented into place at the uppermost portion of the well for the specific purpose of protecting groundwater. Multiple strings of casing are used to ensure groundwater protection. As the well is drilled deeper, additional casing and cement is installed to isolate NG producing formations from ground water.	-Uses on site real-time monitoring of its frac operations to ensure every aspect of the frac process is performed in an environmentally appropriate and safe manner.
Chesapeake	-Recycles produced water as much as practical; stores produced water in enclosed surface water tanks with secondary containment until disposed of in a government-approved underground injection control well. -"Aqua Renew" program uses proprietary technology to recycle	-Discloses ingredients used in hydraulic fracturing fluids to state agencies and the hydraulic fracturing chemical disclosure registry at www.FracFocus.org . -"Green Frac" program to evaluate the types of chemical additives to determine their environmental friendliness;	-Uses the most current technology practical to reduce likelihood of spills. -Solar panels at a West Texas well power telemetry systems that provide pumpers with real-time information on oil and water tank levels to alarm them when levels near capacity, preventing tank spills.	

Table 25: Overview of selective actions taken by companies to reduce HSE-related risks for shale gas

	Water use	Chemicals	Spills	Other
Chief O&G	produced water in Barnett & Marcellus operations -Works collaboratively with federal, state and local agencies to ensure that water used for deep shale natural gas and oil development is consistent with water use plans for the relevant watershed. -Recycles a large portion of flowback water produced in the fracking process; All flowback is stored in steel tanks before recycling; flowback is then transported from one pad site to another by contracted licensed water haulers for the next hydraulic fracturing operation, where it is filtered, and then blended with fresh water at a low ratio, for re-use.	elimination of any additive not critical to the successful completion of the well -Participant in FracFocus*	-Lines all surfaces around its drilling and hydraulic fracture operations with 30 to 60mm plastic liners to contain spills and prevent fluids from coming into contact with the environment. -Any spills are immediately vacuumed off the containment and disposed of safely.	The use of advanced technology, best practices and many extra precautions are taken to preserve the water quality in nearby rivers, streams and water wells. And water use and disposal are managed with equally high standards and regulatory oversight by state agencies.
Devon Energy	-Commitment to using water that is unsuitable for drinking, livestock or irrigation -In north Texas, it has pioneered water recycling, using thermal distillation technology to reclaim water recovered from well completion operations. -In Wyoming, potable water from wells serves wildlife and ranching needs.	--Participant in FracFocus*	-Emergency response plan, including public notification protocol and safety procedures; emergency reporting procedures for spill containment and management.	
El Paso	-Designs wells and production pipe to isolate producing formations from freshwater zones and the environment. -Uses recycled paper mill wastewater in some of its hydraulic fracturing operations. -Flowback is collected at the surface for disposal and evaluated for recycling in other hydraulic fracturing operations; injects flowback water from its fracturing operations into wells specifically designed and permitted for the safe disposal of flowback water. -Pilot testing treatment technologies that allow the treatment and reuse of produced water (natural salt water released from the shale) as a means to reduce our overall fresh water demand.	-Participant in FracFocus* -Evaluates chemical use and looks for opportunities to reduce the number and volume of chemicals used across its operations, including hydraulic fracturing operations.	-Once the surface casing is set, one or more additional intermediate casings and a production casing are installed and cemented; cement is tested before the cement is pumped into the annulus; intermediate and production casings are then installed, cemented, and pressure-tested. In cases where it is desirable to know the location of the top of the cement, the production casing may be tested using acoustic sound testing in addition to pressure-testing.	-"CleanStream" process uses ultraviolet light instead of additives to control bacteria in water, reducing the amount of biocide needed to complete a well.
EOG Resources	-Attempts to minimize the use of water from sources that are also utilized for public drinking water; has utilised brackish water aquifers as source water for some of its hydraulic fracturing operations; fresh water is efficiently handled to avoid waste by installing a system of connected holding ponds lined with impervious plastic. -As part of the recycling process, particulates are filtered from the water (10 micron filter) and the flowback water is tested to determine appropriate quantities of additives and dilution before reuse for fracking. -One of the founding members of the Barnett Shale Water Conservation and Management Committee: committed to developing efficient and responsible best	--Participant in FracFocus* -Working to promote transparency in the disclosure of the fluids used in the hydraulic fracturing process, while respecting the IP rights of the manufacturers supplying the additives.	-All completion fluid and flowback/formation water is stored in lined tanks; special protective liners are placed on the well pad under the lined storage tanks and under the area where trucks deliver the fluids; additional containment barriers are placed around the circumference of each well pad.	

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Table 25: Overview of selective actions taken by companies to reduce HSE-related risks for shale gas

	Water use	Chemicals	Spills	Other
EQT	management practices for water used during drilling, completion and production operations -Uses water recycled from previously fractured wells and obtained from freshwater sources. This water is mixed with sand and a small percentage (less than 0.3%) of chemicals.	-Participant in FracFocus*	-Well construction practices include installation of multiple layers of protective steel casing surrounded by cement that is specifically designed and installed to protect freshwater aquifers. -Manages fluids to prevent potential spills, resulting in a company record on spill reporting and reduction. -Has tied spill reduction performance and environmentally responsible practices into employee incentive rewards	
Marathon Oil	-Testing methods of recycling flowback fluids and reusing produced water.	-Participant in FracFocus*	-Provides training, procedures, preventive maintenance, equipment inspections and mechanical safeguards; investigates spills to identify their causes and take incident-specific corrective actions to prevent recurrence; broad corrective actions are taken where appropriate.	-To prevent water contamination, its fracking treatments are designed for specific well site and reservoir conditions and are conducted using rigid engineering controls; typically performed on wells with true vertical depths greater than 5,000 feet, well below most fresh water sources.
Newfield	-By treating flowback on location 75% of the volume treated becomes clean water; other 25% becomes concentrated brine water, which is re-used in subsequent hydraulic fracturing operations.	-Participant in FracFocus*	-Comprehensive plans in place	
Range Resources	-Treatment design advancement with service provider partnerships with focus on salt water use (recycling).	-Participant in FracFocus*.	-Maintains a series of onsite preventative technologies, such as absorbent materials to soak up a spill and accessible water to flush and eliminate spills.	
Seneca Resources Corp.	-Removes fluids from the well and recycles the water, sand and chemical mixture ("frac fluid") to use in other well operations. Any frac fluid that is not recycled is treated to remove and clean the water. -Goal is to recycle 100% of all frac fluid, resulting in zero discharge in its operations.	-Participant in FracFocus*		-Working toward developing beneficial use applications for its drill cuttings and/or frac fluid, attempting to recycle and re-use filtered and treated flowback and production waters.
Shell	-Test potable groundwater before and after it drills to help determine whether changes have occurred as a result of activity. -Recycles as much water at each project as reasonably practicable. In the Marcellus Shale, Shell recycles almost 100% of produced fluids, substantially reducing both fluid waste and the amount of water needed for hydraulic fracturing. -Designs its completion and production activities in order to isolate them from potable groundwater aquifers.	-Participant in FracFocus*	-Builds in 2+ barrier layers in all wells and for surface storage of fluids produced from the wells. Also, designs steel casing and cement to protect and isolate the potable groundwater zone from the production stream, as well as hydraulic fracturing fluids, in the wellbore. -Keeps well construction and producing activities no less than 1500 feet (457m) away from legally protected surface water bodies within the same watershed.	-Uses only air, water, or water-based drilling mud through and to at least 500 feet (150m) below the potable groundwater aquifer and case and cements that zone before drilling further or hydraulic fracturing. -Assess the impacts of its operations on the social and economic life of the community and looks for ways to reduce the consequences and strengthen the opportunities; will identify local opportunities for strategic social investment contributions and partnerships; pursues opportunities to train and hire staff locally.
Southwestern	-Constructed 100+ ponds that have the potential to capture 50mn bbl of water. As a result, less than 5% of the water for its drilling operations now comes from	-Participant in FracFocus*	-Internal web-based incident reporting system that requires initial reporting of spills as well as any third-party documentation or notifications to	-Development of 3D seismic imaging enables exploration teams to more easily identify NG prospects, place wells more effectively, reduce the number of

28 September 2011

Table 25: Overview of selective actions taken by companies to reduce HSE-related risks for shale gas

	Water use state waterways.	Chemicals	Spills agencies or landowners; database to send incident report to designated persons so they can respond appropriately.	Other dry holes drilled, reduce drilling costs, and cut exploration time. -Evaluates the geographical and topographical aspects of each site to determine the best place to locate a well; where practical, it minimizes its emission profile during well completion activities by employing "green completion" technology which allows it to capture gaseous emissions, including methane.
Talisman Energy	-Focused on recycling water to reduce the amount of fresh water used in developments. This involves recovering flowback water (fracturing fluid that flows back through the wellbore to the surface), storing it and reusing it to fracture future wells. -Since mid-2010, it has achieved nearly 100% reuse of flowback water in Pennsylvania. Reuse of flowback water reduces the cost of offsite waste disposal and helps to conserve water resources.	Participant in FracFocus* -Lists fracturing chemicals for all of its shale gas developments across North America on both corporate and Talisman Energy USA websites.	-Tracks and records spills across its global operations as a key indicator of environmental performance. In 2010, the number of spills greater than one-half barrel in its global operations decreased from 157 in 2009 to 109. -Installed plastic liners under drilling and completion sites in order to prevent any spilled fluids from reaching the environment.	-Follows stringent wellbore casing techniques that meet or exceed industry guidelines designed to protect fresh water and also monitors practices and strives for continuous improvement in each well program. -Upgraded connector equipment to help prevent leaks, introduced new operating procedures for tanks and increased spill prevention training for its field staff.

Source: Company websites and disclosure. * FracFocus is a joint project of the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission

Appendix 2: EU member states measures on shale gas

Overview of country-level actions on shale gas in greater Europe

Country	Legislation	Positives for development	Negatives for development
Austria	-The Mineral Resources Law is a 1--stop-shop procedure. -Very stringent water protection laws: authorities must be consulted when large quantities of water are used in mining; local nature protection: drilling developments also require permission.		
France	-Lower house of parliament approved a bill that bans hydraulic fracking and revokes existing shale gas permits.	-Amendments to the law will allow scientific research to be conducted on shale gas and oil and its environmental impact, albeit under the control of state. -A preliminary report on the economic and ESG issues on shale gas is favourable to drilling, but under strict controls.	-If companies fail to report the use of the banned technology and are found to be using it, executives could face a €75,000 (\$107,000) fine and prison sentences. - Strong stakeholder opposition (political parties, trade unions, local communities)
Germany	-Falls under the Mining laws, but many regulations are not relevant to shale technologies.	-Federal Government appears supportive; German Research Centre for Geosciences (GFZ) has received € 7.1mn from the Ministry of Research, to explore potential unconventional gas potential	-North Rhine-Westphalia state government is pushing for increased regulation -Green Party members of the German parliament want greater regulation / stakeholder involvement -Stakeholder concerns over the environment, incl. contamination of groundwater, as well as earthquakes
Italy		-Government believes development would help reduce the need for EU imports, hence lowering prices and strengthening the hand in negotiations for other fossil fuels	
Netherlands		-Dutch Energy Council (Algemene Energieraad), the highest advisory body of the Dutch government in energy affairs, has come out strongly in favour of the development of unconventional gas; believes current environmental legislation in NL and EU is fully adequate on environmental issues; prefers gas to coal with CCS; sees business opportunities for the Netherlands in tackling the environmental challenges associated with unconventional gas production, for instance in water management, in which the Netherlands has a lot of know-how.	-Local stakeholder opposition (i.e. Bontel development) but more muted than France or Germany
Poland	-Lower house of the parliament (Sejm) has adopted a new geology and mining bill, according to which the National Fund for Environmental Protection and Water Management (NFOSiGW) will only get 10% of the proceeds from mining concessions and fees. -Licensing Exploration: Ministry of Environment may cancel the licence or modify it if the licence rules are breached or obligations are not met -Licence application must conform with the rules of Geological Mining Law: An environmental impact study is required. Consultations with local environmental representatives	-Government is looking to use shale gas deposits in order to improve the country's energy security -Poland's Ministry of the Environment says Polish shale gas is "the gold rush of the 21st century," while other officials have spoken of Poland as the "next Norway" and a future "energy super-power." -Working closely with the U.S., signing on to the U.S. State Department's Global Shale Gas Initiative -Deposits situated in sparsely populated areas, lowering the likelihood of resistance from local residents	EU-level HSE legislation
Spain			
Sweden		Re-election of the centre-right coalition likely means that Sweden's position towards shale gas exploration will remain unchanged	-Opposition alliance led by Social Democrats in partnership with the Greens and Left Party has spoken out against shale gas exploration -Stakeholder opposition from local residents and activists over environmental issues and water supply.
UK	-Fracking is not mentioned in UK legislation; the Environment Agency is currently developing policy	-UK energy and climate change committee came out against a ban on fracking in May 2011, finding	-Some of the gas is under very heavily populated areas of the country: approval could be difficult,

Overview of country-level actions on shale gas in greater Europe

Country	Legislation	Positives for development	Negatives for development
	at the national level on shale gas permitting and 'fracking' will probably not be able to go ahead without a permit	no evidence that fracking posed a direct risk to underground water aquifers and arguing that shale gas could improve national energy security. It said environmental problems associated with it in the US could be overcome by tight regulation and good industry practice.	especially after a stakeholder backlash following earthquakes -NGO opposition i.e. WWF-UK: At the very least, given the current lack of understanding of the environmental risks and hazards associated with shale gas, WWF considers that no shale gas related activity should be undertaken. It believes that the UK government should issue a moratorium on shale gas operations until the environmental implications are fully understood
Ukraine	-Ukrainian Parliament has passed investor-friendly legislation aimed at opening its domestic natural gas market to shale gas producers.	-Deputy PM stated in 2010 that Ukraine planned to double natural gas production to 1.4tn ft3 p.a., with help" a large percentage of this coming from unconventional coalbed methane and shale gas -Ukraine plans to begin production of shale gas in 5-7 years, according to its Minister of Fuel and Coal Industry	-Russia has warned Ukraine that shale gas "won't gas the country to reduce its reliance on Russia's gas

Source: Government websites, company and press sources

Appendix 3: Overview of shale gas HSE incidents

Table 26: Selection of shale gas HSE incidents

Date	Company	Incident Details	Location	Hazard(s)	Amount	Remediation Efforts
Aug 08 - Jul 09	Atlas Energy Resources LLC	Atlas Energy Resources LLC charged with improper planning, maintenance, & dumping	Several sites throughout Fayette, Greene & Washington Counties, PA	Diesel fuel & production fluids	Unknown	The PA DEP fined Atlas \$85,000 for the violations that occurred between Dec. 2008 & July 2009.
Jan-09	Cabot Oil & Gas	Methane gas leaked into drinking water, then home, following nearby natural gas hydraulic fracturing	Dimock, Susquehanna County, PA	Methane gas, fire	Unknown	In February, the PA DEP charged Cabot Oil & Gas with two violations that it says caused the contamination, theorizing that gas leaked from the well casing into fractures underground. DEP ordered Range Resources - Appalachia LLC & Chief Oil & Gas LLC to suspend a portion of their operations. The orders will remain in effect until the DEP has received & approved a water management plan from both companies, & each firm has obtained the necessary permits.
May-09	Range Resources - Appalachia LLC & Chief Oil & Gas LLC	The impoundments draw significant amounts of water per day from nearby waterways. Such large volume diversions could impair the existing uses of the waterways.	Cogan House Township & Mifflin Township, Lycoming County, PA	Water withdrawal	n/a	DEP fined Range Resources as of January 2010.
Jun-09	Range Resources	A leaking waste water pipe from a Range Resources Marcellus shale gas well drilled in polluted water, killing fish, salamanders, crayfish & aquatic insect life.	Cross Creek Lake, Washington County, PA	Returned frac fluid, waste water discharge	Unknown	
Jun-09	Stallion Oilfield Services	"DEP conducted an inspection at Stallion in June 2009 and discovered that the company was operating a fracking water transfer station without the required DEP permit." DEP inspectors also found a 450-square foot area where fracking water had spilled onto the ground. Soil samples showed high levels of chlorides and barium, which are common constituents of fracking water.	Williamsport	Frac fluid	n/a	Fine of \$6500; Stallion subsequently excavated and properly disposed of about seven cubic yards of soil.
Sep-09	Consol Energy	A toxic algae bloom resulted in a massive fish kill (complete mussel kill). Favorable algae growth conditions were caused by high TDS levels, dry weather & water withdrawals for fracturing operations.	Along 43 miles of Dunkard Creek (Along WV & PA border)	Golden algae	Unknown	Lower chlorides & TDS levels. Consol Energy is now allowed to pump out water from its Blackville No. 2 mine on specific conditions issued by the WV DEP.
Sep-09	Cabot Oil & Gas Corp.	Cabot Oil & Gas Corp. experienced 3 separate spills in less than 1 week, which polluted Stevens Creek & a nearby wetland.	Heitsman well in Dimock Township, PA	Water/fluid mixture, paraffinic solvent & poly-saccharide	8,000 gallons	The DEP's order stopped all hydro fracking operations at each site throughout the county. Cabot has since submitted the necessary forms according to DEP specifications, & resumed operations.
Oct-09	Range Resources	A Range Resources temporary above-ground water transfer line connection failed. Minnows, crawfish & frogs died / were impaired.	Brush Run Creek, Hopewell Township, Pa	Partially recycled flowback & fresh water, chlorides	250 barrels (10,500 gallons)	PA DEP officials inspected about 4/10 of a mile of Brush Run near the spill. Fines for this incident have not yet been published, but should be announced in spring 2010.
Feb-10	Fortuna Energy Inc.	Proper ownership information missing, flow-back fluids discharging into tributary	3 natural gas wells, Troy Township, Bradford County, PA	Flow-back fluids	Unknown	Fortuna Energy Inc. promptly placed a pump into the sediment basin to pump the fluids back into tanks & hired a consultant to conduct appropriate sampling. PA DEP has fined the company \$3,500 for the violations.
Mar-10	Talisman Energy	PA Department of Environmental Protection announced that it has fined Talisman Energy \$24,608 for a large diesel fuel spill that occurred in March 2010 in Bradford County. The spill happened at the Putnam 77 Marcellus natural gas well pad in Armenia Township.	Bradford county	Diesel fuel spill	n/a	Fine of \$24,608; Cleaning up the spill required the excavation and removal of 3,800 tons of contaminated soil. It also meant collecting some 132,000 gallons of contaminated water - from which 450 gallons of diesel fuel was recovered.
Mar-10	General Energy	A substance used in the natural gas drilling process was discoloring & distorting the texture of spring water runoff.	Cummings Township, PA	Airfoam HD	Unknown	Representatives of PA General Energy, w/whom DEP members have been communicating, are investigating the problem
Mar-10	Range Resources	Range Resources: Broken pipe & flushing of water in field	Hickory, PA (Caldwell St.)	Water (unknown)	Unknown	PA DEP investigating. Incident reported to researchers by witness.

Table 26: Selection of shale gas HSE incidents

Date	Company	Incident Details	Location	Hazard(s)	Amount	Remediation Efforts
Mar-10	Anadarko Corp.	Mud overflowed Anadarko Corp. well pad	Sproul State Forest, PA	components) Mud used as a cooling agent	8,000 - 12,000 gallons	A contractor has begun cleanup.
Mar-10	Atlas Energy	Atlas Energy gas well fire (natural gas storage tank or liner)	Hopewell Township, PA	Fire, smoke	n/a	Emergency personnel let the fire burn itself out. Investigation being conducted.
Apr-10	Cabot Oil & Gas Corp	Cabot Oil & Gas Corp violated PA's Clean Streams Law and the Oil & Gas Act by failing to fix defective cement & well casings on certain wells and to prevent the unpermitted natural gas discharge into groundwater.	Dimock, PA	Migrating natural gas	Unknown	Cabot must plug 3 wells within 40 days & install permanent treatment systems in affected homes within 30 days. PA DEP suspending its review of Cabot's permit applications for new drilling activities statewide until the order is fulfilled. Cabot barred from drilling new wells for at least 1 year in the area.
Apr-10	Stallion Oilfield Services	Stallion Oilfield Services operated a transfer station without a permit last year.	Old Lycoming Township, Lycoming County, PA	n/a	n/a	PA DEP fined the company \$6,500.
Apr-10	n/a	Residents reported strong gas odours	Washington & Greene Counties, PA	Unknown	Unknown	PA DEP investigating & taking air samples. Any entity that is found to be operating a source of odours may be fined up to \$25,000 under the Air Pollution Control Act.
May-10	Chief Oil & Gas	Chief Oil & Gas withdrew water from the Casselman River without a permit. Water-hauling trucks caused boat dock damage.	Jefferson Township, PA	n/a	n/a	PA DEP cited the company and will meet with Chief over the permitting confusion. Chief has pledged to repair the boat dock.
June-10 (Approx)	Cabot Oil & Gas Corp.	Fluid leak into the ground water caused by a hole in the pit liner	Dimock, Susquehanna County, PA	Black drilling liquid	Unknown	PA DEP issued a notice of violation to Cabot Oil & Gas
Apr-11	Chesapeake Energy Corp.	A gas well in Pennsylvania exploded in April and sent thousands of gallons of fluids through the drilling site and into a local tributary. The fluids contained dangerous chemicals, forcing seven families to evacuate their homes.	Pennsylvania, New York	Frac fluid	n/a	Fine of \$900,000 for contamination of private water supplies \$188,000 for a tank fire that injured 3 workers
Jun-11	Cuadrilla Resources	Its activities may have triggered two small earthquakes near a test well close to Blackpool.	Blackpool, UK	Earthquakes	n/a	Suspending operations until the investigation is complete

Source: Company and press sources

Table of companies mentioned

Table 27: Table of companies mentioned

Companies Mentioned	BofAML Symbol	Recommendation	Q-R-Q	Price
BAKER HUGHES	BHI	BUY	B-1-7	USD 51
BASF	BFFAF	NEUTRAL	A-2-8	EUR 45
HALLIBURTON	HAL	BUY	C-1-7	USD 34
SCHLUMBERGER	SLB	BUY	B-1-7	USD 63
CAMERON	CAM	BUY	C-1-9	USD 45.79
CHESAPEAKE	CHK	XRVW	XRVW	USD 27.53
GECINA	GECFF	BUY	B-1-8	EUR 64.90
LINDE	LNAGF	NEUTRAL	A-2-7	EUR 98.76
NALCO	NLC	HOLD	HOLD	USD 35
RANGE RESOURCES	RRC	BUY	C-1-7	USD 60
SIEMENS	SMAWF	NEUTRAL	B-2-7	EUR 66
VEOLIA	VEOEF	BUY	B-1-8	EUR 10
EDP RENOVAVEIS	EDRVF	BUY	C-1-9	EUR 4
FIRST SOLAR	FSLR	BUY	C-1-9	USD 72
GDF SUEZ	GDSZF	BUY	B-1-7	EUR 21
IBERDROLA	IBDSF	NEUTRAL	A-2-7	EUR 5
INTERNAT'L POWER	IPRWF	BUY	A-1-8	GBP 316
NEXTERA ENERGY	NEE	BUY	B-1-7	USD 54
SUNPOWER CORP.	SPWRA	UNDERPERFORM	C-3-9	USD 9
VESTAS	VWSYF	UNDERPERFORM	C-3-9	EUR 86

Prices as at 27/09/2011

Source: BofA Merrill Lynch Global Research

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Industrials

Click [here](#) for definitions of commonly used terms.

Macro

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Underperform	N/A	≥ 20%

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