Energy Transformation

SHALE GAS

AN OPPORTUNITY EUROPE CANNOT AFFORD TO MISS

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INTRODUCTION

Over the last ten years or so an energy revolution has taken place in North America, where hydraulic fracturing and associated unconventional gas recovery techniques have brought jobs, growth and energy security, while providing a cheap and clean local fuel to challenge the supremacy of dirty coal and as a backup to renewables. In this report we would like to reflect on the opportunities and challenges this presents for Europe and elsewhere, where the revolution has yet to gain a foothold.

It is still early days for the shale gas industry, a stage when development tends to incur major environmental and social disruption. But that has not been the case with hydraulic fracturing (fracking) for shale gas recovery, despite the associated technology remaining in its infancy. As the sector matures and innovation accelerates there is enormous potential for even cleaner and cheaper development.

The fracking industry has brought an ample supply of clean fuel, low energy prices, energy security, jobs, improved trade balances and industrial growth to the United States, without loss of life or major incident, and yet it faces multiple challenges form a concerned public and vested interests – especially in Europe, where apart from a few glimpses in Poland, the shale gas remains in the ground.

If Europe is to see similar benefits to North America, such objections need to be dealt with carefully and thoroughly, to protect the environment and address public concerns. The environmental argument in favour of more gas – highlighted by current falling coal use in the US and rising use in Europe – needs to be won, and attention must be paid in Europe to the benefits shale gas could bring.

Europe's stagnating and resource-poor economy needs the benefits shale gas development can provide even more than the United States, but only the highest operational standards can be acceptable in such a heavily populated and sensitive region, which will stretch the innovative capabilities of companies focused on the sector.

Those companies are ready and confident they can meet the challenges, minimising environmental risks and impact to avoid any incident that could lead to political rejection. Far more than even driving a car, the risks are trivial compared to the benefits, but this must be ensured and given chance to gain general acceptance.

The power of large and small innovative private companies can address the environmental challenges of shale gas development, enabling even the toughest regulations to be met, just as they drove the technology that led to the unlocking of shale gas over the last twenty years in North America, bringing fuel costs low enough for even the poorest to afford ample heat and power.

As Jacek Krawiec, CEO of PKN Orlen, puts it: "Breakthrough technologies and revolutionary innovations ultimately reduce costs and win the economic competition by providing alternative solutions, a fact consistently proven by each ground-breaking invention in the energy sector."

One message was clear from the latest Society of Petroleum Engineers unconventional conference (the home of shale gas innovators) in the US last July – even in the United States, the shale revolution is only just beginning thanks to technological advances. And those advances are not only protecting the environment and cutting costs, but they are also continuing to expand recoverable reserves year by year – from 100 years gas consumption in the US at current rates in 2012 to 110 years this year, despite rising consumption1. As technology advances more rock types can be tapped and more distant reserves can be reached, while more of what is in existing wells becomes recoverable. This translates into less coal burnt and less oil and gas imported from Russia and the Middle East.

European development hotspots include Poland, Romania, Turkey, The UK and Ukraine. The potential for development is already moving offshore, allowing expansion of hydraulic fracturing into traditional European hydrocarbon producing areas in the North Sea, where social concerns are less pressing.

This report seeks to draw together the reasons why developing shale gas in Europe is an opportunity that the continent cannot afford to miss, together with the real risks associated with it and the technological solutions that can address those risks and enhance the benefits further.

CONTENTS

TECHNOLOGY

"[We must set] clear rules for investors, then decisions are for them... Having social acceptability for [shale gas development] is the most important thing"

— Janez Potocnik, EU Environment Commissioner

EXECUTIVE SUMMARY

While acknowledging the risks and impact of hydraulic fracturing for shale gas, this report seeks to concentrate on the technology that can solve problems associated with it – hopefully going some way to redress an imbalance in the European debate, which has tended to focus on the downside. From our glass-half-full perspective, we discuss how shale gas can pave the way to a low carbon economy, while at the same time bringing jobs, growth and energy security. A single-minded focus on heavily subsidised renewables could be putting at risk development of a home-grown form of clean energy that could cut more greenhouse gas emissions and other pollutants on a global basis than any renewable technology, and whose key impacts and risks can be managed or even removed completely with tight regulation and innovative technology.

The report finds that the main arguments in favour of hydraulic fracturing are in the areas of green-house gas emissions reduction, as shale gas represents the only immediate viable alternative to coal in the developing world and is an essential back-up to intermittent renewables. It also scores highly in job creation, economic growth and security of energy supply. Shale gas is a local resource that requires people, services and investment to get it out, which means wealth is retained at a local level – a potential godsend for Europe's poorer regions.

The risks and impacts are examined, real or perceived. Water use and pollution, along with methane release, are the two areas of greatest concern. On the other hand, science suggests ground water contamination is highly unlikely and easily guarded against, while we need to be reminded that reservoirs and coalmines cause earth tremors too, and if shale gas wells encounter sensitive strata abandonment should always be an option.

Hydraulic fracturing is more of an industrial process than a traditional exploration and production venture, which changes the nature of the industry and creates a different set of risks and impacts as a consequence. Individual wells are far less risky, but more are required, so regulation designed for conventional oil and gas developments must be carefully reworked. The technique's roll out and establishment in North America holds many lessons, from which Europe and others can learn.

Focusing on the debate in Europe, we examine the competitive disadvantage in energy costs currently being borne by European industry and taxpayers, and ask why there is little in the way of policy or strategy to deal with this at a European level, which could – if not addressed – lead to a haemorrhaging of industrial activity. Shale gas can certainly be part of the answer here, helping fulfil European goals in economic and industrial growth, while achieving social goals by ensuring a wide geographical and societal spread of benefits. We argue that it is essential that there is pragmatism in Europe today, and an objective debate that acknowledges the huge potential benefits of unconventional gas and oil recovery, rather than focusing purely on environmental risks.

When it comes to tackling the problems of shale gas development, contributors generally agreed that the area with most potential for a technologically-driven reduction in environmental impact was water use, in particular the use of clean water. There are numerous innovative products, services and research projects focused on cleaning and treatment, through to alternative chemicals to remove the need for clean water, reduce overall use, or eliminate it altogether by using alternative fluids. This kind of technology not only reduces the environmental footprint, but could be critical in determining whether or not fracking is feasible at all in drought prone regions, where local populations have first call on water sources.

"The precision of work performed currently underground by top drilling companies can be likened to dropping a plumb-line from the top of the Empire State Building bending it at a right angle just above the ground and then guiding it through the rear and front windscreens of every car parked in the nearby streets."

— PKN Orlen

Technological progress is also eating into the land required for fracking, reducing local impact. The combination of horizontal directional drilling and fracking has revolutionised the way we are able to access hydrocarbons, and as materials and computer power expands further the combined technique will continue to improve, allowing us to accurately tap sweet spots far from drill sites. Hydrocarbon extraction is becoming precise, cleaner and more efficient.

"The precision of work performed currently underground by top drilling companies can be likened to dropping a plumb-line from the top of the Empire State Building bending it at a right angle just above the ground and then guiding it through the rear and front windscreens of every car parked in the nearby streets.," says PKN Orlen.

While technology can achieve raised standards, there is also a need for regulation to play its part, ensuring enforcement of the highest standards achievable with current technology. Innovation in standards and their application, as well as improved monitoring, was felt to be important - not only for environmental reasons but also to help gain social acceptance, particularly in Europe.

There is little doubt that the use of the latest fracking technology can ensure safe and unobtrusive development, given appropriate and tight regulation. So it should be possible for Europe and elsewhere to enjoy the benefits of shale gas development, while effectively guarding against local environmental impact. The European economy and millions across the continent need the opportunities shale gas can bring. Our report concludes by calling on Europe's policy makers to ensure that this happens. While it is important to gain social acceptance through tough regulation, talking up the potential benefits also helps, and Europe should be doing both.

State of Shale Gas Development in Key Countries Outside North America

Country	Estimate of shale gas Reserves (EIA, Tcf)	Main Shale Gas Investors	Major Shale Plays	Stage of Shale gas development	2020 Forecast/ Potential	Social Opposition/ Regulatory challenges/ Commercial incentive?
Australia	437	Beach, Chevron, Statoil, PetroFrontier, Santos, Total, BG, Drillsearch, Falcon	Cooper Basin, Southern Georgina, Kockatea, Beetaloo Basin	Appraisal, testing, some gas produced	High	Permits awarded. Proven regulatory environment. Limited social opposition in outback.
India	100	ONGC-ConocoPhillips OIL-Carrizo	Cambay Basin	Licensing Arrangement, Initial exploration	Low	Changed mind on allowing Cairn and Reliance shale rights in existing blocks.
China	1115	Shell-Petrochina, Chevron-Petrochina, Petrochina-ConocoPhillips, Sinochem-Hess, Sinopec-Hess, Sinopec-ConocoPhillips, CCM	Sichuan basin, Erdos basin, Bohai Bay, Songliao basin, Jianghan basin, Tuha basin, Tarim basin and Junggar basin	Producing limited quantities	Government target of 60bcm/yr	Conflicting interests being resolved on the ground, steady operating environment developing but regulations not yet finalized. Must partner with local firm.
UK	130 (UKGS – 10% of Bowland TIP)	IGAS, Cuadrilla, Dart, maybe Total	Bowland	Testing	Uncertain	Strong government support, including tax incentives. Social opposition, especially in south
Poland	148	Orlen, San Leon, FX Energy, PGNiG, ConocoPhillips	Baltic Basin, Scinniy Basin, Fences Concession	Testing, some gas produced	Uncertain	Government pro, but technical and commercial questions.
Ukraine	128	Shell-Nadra Yuzivska, Chevron	Yuzivske field, Oleske field	Licenses Approved	Government target of 10% national demand – about 7bcm	National and local government approval secured
Romania	51	Chevron	Dobrogea area, south-east Romania	Permission to drill	Uncertain	Initial ban reversed
Turkey	163 (TPAO)	Cub Energy, Shell-TPAO, TPAO	Dadas Shale (Oil), southeast Anatolia, Thracia	Testing	Good	Fracking used in enhanced oil and gas recovery for 4 years.
South Africa	390	Shell, Chevron, Falcon	Karoo	Technical assessment	Uncertain	New regulations pending, ban lifted.
Argentina	802	YPF-Dow Chemical, Americas Petrogas	Vaca Muerta	Exploratory	Good	Local and national government approval.
Saudi Arabia	600 (Saudi estimate)	Saudi Aramco	Northwest, south Ghawar, Rub' al-Khali	Appraisal and pilot testing	Enough for 1000MW power plant by 2017-8	Development plan in place to supply gas-fired power plant in north, start-up 2017-8

BENEFITS

Unconventional gas as an environmental winner

As a replacement to coal and oil, and as a backup for renewables, locally produced shale gas could prove the biggest contributor to greenhouse gas emissions reduction over the next 30 years, particularly in the developing world where much of the growth in emissions is occurring.

Hydraulic fracturing and the additional locally or regionally sourced gas it can contribute to the energy mix can - and is - helping reduce green-house gas emissions, by replacing the worst polluter of all, coal. Here lies the greatest prize for those concerned over global warming, tackling the single biggest cause - coal use, especially in China and India.

The International Energy Agency predicts that by 2017, coal will replace oil as the dominant primary energy source worldwide, and in 2012 China accounted for more than half of the world's coal use for the first time, according to BP's latest Statistical Review. Consequently, if successful, replacement of coal with gas would contribute far more to our global efforts to cut greenhouse gas emissions than even Europe's impressive moves towards green energy. In combination with renewables, cheaper, local shale gas could help provide a viable alternative to coal, which would mark a significant reversal in the growth of global greenhouse gas emissions.

At the same time gas can take on the other major greenhouse gas producer, oil, in its so far-untouched transportation fuel heartland of gasoline and diesel, which makes up the bulk of oil demand. Unlike power generation, where a case can be made for renewables, there is no commercially viable alternative to petroleum based transport fuels, at least on a global scale unless we are to cover the planet with biofuel crops.

"China will only substitute gas for coal if the gas can be domestically sourced, and that means shale gas."

— Paolo Scaroni, CEO, Eni

In the form of compressed natural gas (CNG) and now liquefied natural gas (LNG), gas is already making inroads in the world's largest motor fuels market in the US, which consumed a staggering 12.5 million barrels per day in 2012, about 70 percent of total US consumption and 15 percent of all global oil demand. Oil is also being replaced in industrial operations, for example five LNG processors in Texas will produce

the clean fuel for oilfield applications in the Gulf of Mexico, which in turn helps developers reduce operating costs.

This is no pipedream, and environmentalists must be won over, if not by the theory then by the evidence to date. The effects are clearly apparent already in the United States, where unconventional gas is plentiful. There carbon dioxide (CO_2) emissions have fallen nearly 12 percent over the past five years, and are currently down to 1996 levels, without the need for any subsidies. Tragically, this progress has been balanced by a rise in coal use in the European Union, particularly in Germany. Here consumption rose 5.1 percent in 2012 compared with the year before, pushing Europe further from its emissions goals, while a failure to invest in unconventional gas production or backup gas generating plant is also undermining the viability of intermittent renewables. Europe is being left behind as others realise the environmental potential this locally sourced, clean fuel can offer.

While some of the emissions reduction in the US is attributable to the economic downturn between 2008 and 2010, an accelerating decline as the economy grows suggests that the transition from coal to natural gas for electricity generation - facilitated by cheap gas from the shale boom – is the biggest factor. And this autumn US gas market analysts are warning of more switching as low gas prices persist after a mild summer.

Gas production is continuing to rise despite low prices, sustained by profitable liquids output, and is helping supply energy-starved northern Mexico with some of the cheapest cross-border gas sales anywhere in the world, as well as providing large volumes for upcoming LNG export schemes – all substituting coal and oil use and cutting CO_2 emissions. Of all areas of green-house gas reduction, coal substitution has the greatest practical potential, something environmental groups – which have so far largely opposed shale gas development – need to be convinced of. This is the area where we can realistically make the biggest practical impact on green-house gas emissions, and it can be done without costly subsidies.

“China will only substitute gas for coal if the gas can be domestically sourced, and that means shale gas,” said Paolo Scaroni, CEO of Italian multinational oil and gas company Eni.

If gas cannot compete with coal, then coal use rises again and carbon dioxide emissions with it. China will not be able to afford to replace much of its massive coal use with LNG imported from half way across the globe, or with expensive gas piped thousands of miles from Russia – the main hope to replace the hundreds of gigawatts of highly polluting Chinese and Indian coal power stations is from unconventional gas produced in the heart of China (and possibly India) at a price that is affordable, and with minimal environmental impact.

“Shale gas is good for consumers and bad for energy companies, because it brings prices down,” Scaroni said.

Essential Backup

To add to its environmental credentials as a replacement for coal and oil, gas is all but essential as a back-up for intermittent and variable renewables, in particular solar and wind. Until technology for storing electricity is developed, demand must be instantly met with generated power. Gas units are highly efficient, can be quickly powered up as sun or wind fail, and represent the lowest carbon alternative to the intermittent supply, apart from other renewables such as biomass, which are limited and have longer lead times.

To sum up, given the right conditions the International Energy Agency (IEA) estimated in its World Energy Outlook 20123 that greater availability of gas from shale development would have a strong moderating impact on gas prices and, as a result, global gas demand could rise by more than 50% between 2010 and 2035 - cutting the world’s reliance on coal, and bringing down global warming fears with it.

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— Paolo Scaroni, CEO, Eni

The Economic Case for Fracking

Maria van der Hoeven, Executive Director, International Energy Agency

It could be claimed that there is nothing more European political leaders could do for the mass ranks of unemployed and highly skilled European youth – perhaps Europe's biggest long term economic and social problem - than encourage an environment where domestic shale gas can be developed. A recent IHS Global Insight study4 estimated that US shale gas production, which currently represents about 34 percent of total US production, supported more than 600,000 jobs in 2010, a number that is projected to grow to nearly 870,000 by 2015.

Shale gas development has a high 'employment multiplier'— the indirect and induced jobs created to support an industry. Most of the money that goes into fracking is recycled locally and for every direct job created in the shale gas sector, more than three indirect and induced jobs are created, according to the report.

"New [shale gas] supply from the US will moderate prices in other regional markets. Climate impact is positive, as coal is displaced"

— Maria van der Hoeven, Executive Director, IEA

The total does not include job creation in industries that would refocus investment back to the US due to lower energy and feedstock costs (for instance, petrochemicals – many of which may indeed relocate from Europe). The study also found that shale gas and related jobs pay higher wages on average – currently $23.16 per hour – than those paid to workers in manufacturing, transportation and education.

PKN Orlen says: "Our recent research5 shows that the shale gas industry in Poland under accelerated growth scenario could create half a million new jobs by 2025, cutting the unemployment rate by 3 percent. Tax income is forecast to reach $26 billion in the first decade, while growth could be boosted by up to 0.8 percent per year."

In terms of economic expansion, the IHS report claims the shale gas contribution to US Gross Domestic Product (GDP) was more than $76.9 billion in 2010; in 2015 it will be $118.2 billion and will triple to $231.1 billion in 2035, generating a cumulative total of more than $933 billion in tax revenues for local, state and federal governments. It has also improved the US trade deficit, of which a staggering 50% is made up of oil import costs.

In the US, savings from lower natural gas prices, as well as the associated lower prices for other consumer purchases, equate to an annual average addition of $926 in disposable income per household between 2012 and 2015, and increase to more than $2,000/year per household in 2035 – IHS Global Insight.

Europe has set itself the goal of an industrial renaissance, lifting manufacturing's share of the economy to 20 percent by 2020, but high energy costs - especially compared to costs

faced by competitors in North America - are causing many intensive energy users to move elsewhere. The situation is so bad that, speaking at a recent FT conference on shale resources, Mr Scaroni, CEO of Eni, (which ensures gas supply to much of Italy), said that unless shale gas is developed Europe might have to rely on "non-commercial deals" with Gazprom and other major non-European gas suppliers, who may be "persuaded to cut prices to preserve European industry" and with it a long term market for their gas. Eni can claim some success in renegotiating contracts with Gazprom, but it may not be enough for European industry if gas prices in North America remain at less than a third of European levels.

Speaking at the same conference, the International Energy Agency's Executive Director, Maria van der Hoeven, (who was also interviewed for this report – see below), cautioned that current low US gas prices were sustained only by more lucrative liquids production. As liquids-rich acreage is exhausted developers will have to move onto dry gas, which will require a higher gas price to sustain output. "Nevertheless it still leaves the US in a more competitive position versus Europe", she said.

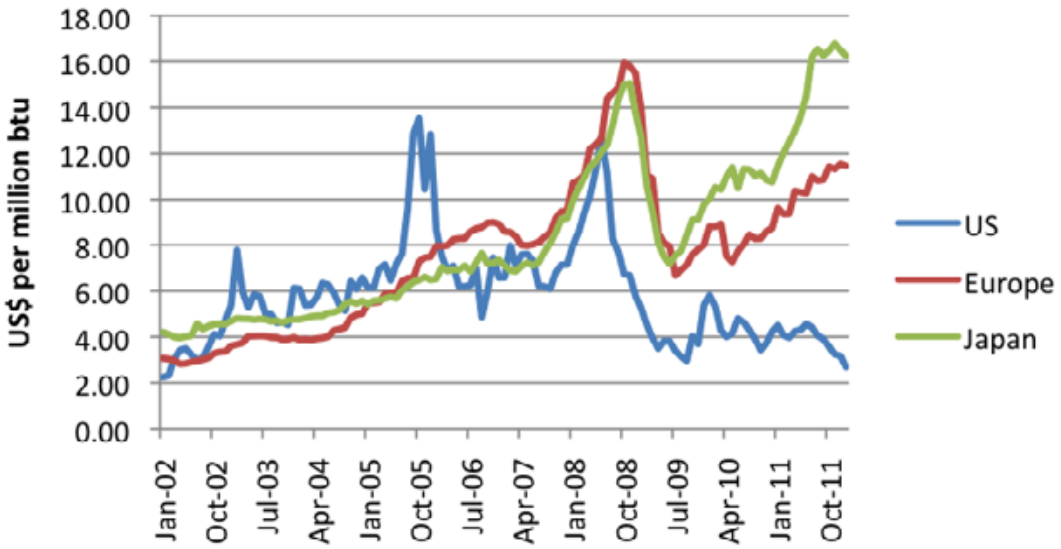
The IHS Global Insight study also measured the broader impact of shale production on gas prices, finding that over the 2010-2035 period prices on average would be at least two times higher in the US without shale gas. This impact is even greater now and over the next few years when prices would have been two-and-a-half to three times higher. The lower natural gas prices have resulted in a 10 percent reduction in electricity costs nationally and that flows through the economy to lead to lower prices for many other consumer purchases. These lower gas prices also boost the international competitiveness of US manufacturers, resulting in 2.9 percent higher industrial production by 2017 and 4.7 percent higher production by 2035.

Shale gas tends to be widely spread and benefits are generated locally, providing a secure domestic source of energy to major energy consuming countries. The IEA estimates that given the right conditions, countries that were net importers of gas in 2010 (including the US) will account for more than three-quarters of total unconventional upstream investment, gaining the wider economic benefits associated with improved energy trade balances and lower energy prices. The investment reflects the high number of wells required: more than one million new unconventional gas wells worldwide between now and 2035, twice the total number of gas wells currently producing in the US.

Development of shale gas means a more diverse mix of sources of gas, helping develop affordable and reliable markets. Domestic production would slow the growth in Chinese gas import needs, while higher US production allows for gas exports from North America - both of which increase the volume of gas, particularly liquefied natural gas (LNG), looking for buyers. This should stimulate the development of a more liquid and competitive international market and lower import costs of gas to markets outside the US, including Europe.

"New [shale gas] supply from the US will moderate prices in other regional markets. Climate impact is positive, as coal is displaced, but at the end of the day gas is not the answer just a very good ally," said Van der Hoeven, referring to gas as a transition fuel to a global low carbon economy.

Price of US gas 2005-present, compared to UK spot price and average Japanese price



Source: Financialsense.com, based on World Bank Commodity Price Data

Security of Supply

"It is projected that in 2010–2035 natural gas consumption in Europe will rise by 63 billion cubic meters (565 bcm in 2035 vs. 502 bcm in 2010). Over the same time, the amount of [conventional] gas produced in Europe is expected to fall by 79 bcm - nearly 45% (to 97 bcm in 2035, from 176 bcm in 2010). This will add a further 139 bcm to the demand for imported gas, and (if no new indigenous production starts) will compound Europe's dependence on imports," says PKN Orlen.

As recently as 2007, it was believed that the US would soon need to import large volumes of imported gas and LNG for domestic consumption. Instead, shale gas production has more than doubled the size of the discovered natural gas resource in North America—enough to satisfy more than 110 years of consumption at current rates.

What's more, estimates suggesting the United States has a 100 year supply of natural gas are based on current technology and, more importantly, exclude the possibility of further technological advances. So it is likely to rise year on year as recovery technology continues to improve. This year the US Potential Gas Committee's biennial assessment of technologically available natural gas resources report1 showed the US now holds an all-time high of 2,384 trillion cubic feet (Tcf) of recoverable natural gas - a 22 percent increase from just two years ago. The new estimate indicates a 110-year supply at current consumption rates.

"Shale gas is an opportunity to 'de-politicize' the global energy market."

— PKN Orlen

Advances in horizontal drilling and hydraulic fracturing are also responsible for a surge in US oil production, reserves and consequent security of supply. From a steady decline between 1970 and 2008, US production is rising quickly again, and could even contribute to a self-sufficient North America by 2035, thanks to the combined application of these two technologies. There has been a general tendency to underestimate the importance of technology in increasing hydrocarbon reserves. Expect this to continue – for example, leading North American shale gas producer, Range Resources, holds a resource potential up to 13 times its proved reserves.

Beyond North America the outlook for supply security depends on more concerted development, although given that the basic technology has already been developed in the US, resources elsewhere are technically recoverable (with adaption to local conditions) and therefore enhance longer term energy security, even if they are not yet producing. It should be remembered that only one shale in the US, Floyd, proved difficult to develop from many differing plays - a pattern likely to be repeated on average across the world.

The IEA, which represents energy consuming nations, sees shale gas as a partial answer to many of the energy security concerns of its members, but it continues to emphasise regulation and standards over benefits (see below) – not that the two are mutually exclusive. In Europe most developers are keen for tight regulation to ensure accidents and consequent bad publicity are avoided.

It estimates that, given the right conditions, development of shale gas resources and other unconventional gas will have far-reaching consequences for global energy markets, with output more than tripling to 1.6 trillion cubic metres in 2035, with most of the increase coming after 2020, reflecting the time needed for new producing countries to establish a commercial industry.

Geopolitical Relief

"Shale gas is an opportunity to 'de-politicize' the global energy market," says PKN Orlen.

Given the widespread geography of shale gas deposits, the largest producers

of unconventional gas would also be biggest consuming countries – unlike the conventional gas or oil scene - reducing reliance on expensive energy imports from unstable regions and monopolies.

Given the right conditions, the IEA expects the US to move ahead of Russia as the largest global natural gas producer, and China, whose large unconventional resource base allows for very rapid growth in unconventional production starting towards 2020, will also become a major producer. There are also large increases in Australia, India, Canada and Indonesia. The IEA believes unconventional gas production in the EU, led by Poland, will be sufficient after 2020 to offset continued decline in conventional output, reducing reliance on large monopolistic state-run suppliers such as Russia's Gazprom or Norway's Statoil.

The share of Russia and countries in the Middle East in international gas trade will fall if shale gas is developed, from around 45 percent in 2010 to 35 percent in 2035 says the IEA, although their gas exports still increase by 20 percent over the same period.

But without effective shale gas development – primarily because of a lack of public acceptance – only a small share of the unconventional gas resource base is accessible, and the IEA says gas production would stagnate. To date, the shale gas industry has indeed proved difficult to get going outside North America. In its Oil and Gas reality Check 20136, advisors Deloitte expects shale gas to remain a largely regional resource, at least for the next three years.

Less developed oil and gas service and financial sectors outside the US are often cited as disadvantages, and the lack of ownership of subsurface resources by individuals, means there is less incentive for local populations to develop shale resources. But successful development in Canada, where there are no private subsurface ownership rules, shows it can be done. And in the UK, the government has been working towards ensuring that those living near planned shale projects stand to benefit economically from operations in the area, while developers have been seeking to use potential customers' land in exchange for the supply of cheap gas.

But if development does not spread, the IEA says the lower availability and higher gas prices that result will mean the share of gas in global energy use increases only slightly, and "the preeminent positions of geopolitical power that Russia, Qatar and the other main conventional gas resource-holders enjoy in global energy supply are reinforced."

Enhanced Recovery: Coming Frack for More

"Only recovering small percentage from wells is criminal… Technology provides the way to maximise extraction from each well," says Mark Zoback of Stanford University.

Fracking could have the potential to double or treble the reserves associated with every existing oil and gas well, according to some experts, because it should be possible to extract up to three times as much – this will reduce the overall impact on the environment, for the same volume of hydrocarbons. Currently only a small proportion of the hydrocarbons in conventional fields are recoverable, but as Enhanced Oil & Gas Recovery (EOGR) techniques, including fracking, continue to be developed, more and more of the resource can be reached.

"Scalability, where multiple wells are drilled from single pads over a wide area, transforms the gas extraction into a lower cost industrial process, which can be enhanced with the use of new technology," says Remi Eriksen, CEO of DNV.

Environmental impact and risk

"When comparing risk at an onshore hydraulically fractured well with a conventional offshore well that could be drilled deep into a high pressure and temperature target in remote areas, then there is no comparison – the conventional well is far more risky. You will not get blowouts [with shale drilling]. The risks are an order of magnitude lower,"said Remi Eriksen, CEO of DNV.

While each individual well is not as risky as conventional drilling, producing unconventional gas is an intensive industrial process, generally imposing a larger environmental footprint per unit of gas extracted than conventional development. More wells are often needed, which can have implications for local communities, increasing land use and demands on water resources. Serious hazards, including the potential for air pollution and for contamination of surface and groundwater, must be successfully addressed. Greenhouse-gas emissions must be minimised both at the point of production and throughout the entire natural gas supply chain. If not addressed properly, these concerns threaten the environment, which would strengthen opposition to development, especially in heavily populated areas like Europe.

But while there are real risks to shale gas development, there is also a great deal of misinformation and ignorance, along with vague objections more to do with social fashion than hard facts – so much so that some clothes retailers in the UK, for example, are closely associating themselves with the anti-fracking movement. Nevertheless, these positions are often strongly held, and safeguards are necessary, while anecdotal cases from the US warrant investigation – but it should be remembered that the absence of regulation in some parts of the US when shale gas development first began almost invited an accident, yet no loss of life or major incident has yet occurred. No-one is advocating such an unregulated approach elsewhere, least of all Europe.

Lars Sorum, DNV's Head of Unconventionals - "Europe is pre-occupied with below ground risks – seismicity, ground water and so on - but risks are predominantly on the surface, including flow back water and treatment, methane release and roads in and out of the area."

> **"Europe is pre-occupied with below ground risks"**
>
> **— Lars Sorum, DNV's Head of Unconventionals**

According to the IEA, governments need to devise appropriate regulatory regimes, based on sound science and high-quality data, with sufficient compliance staff and guaranteed public access to information.

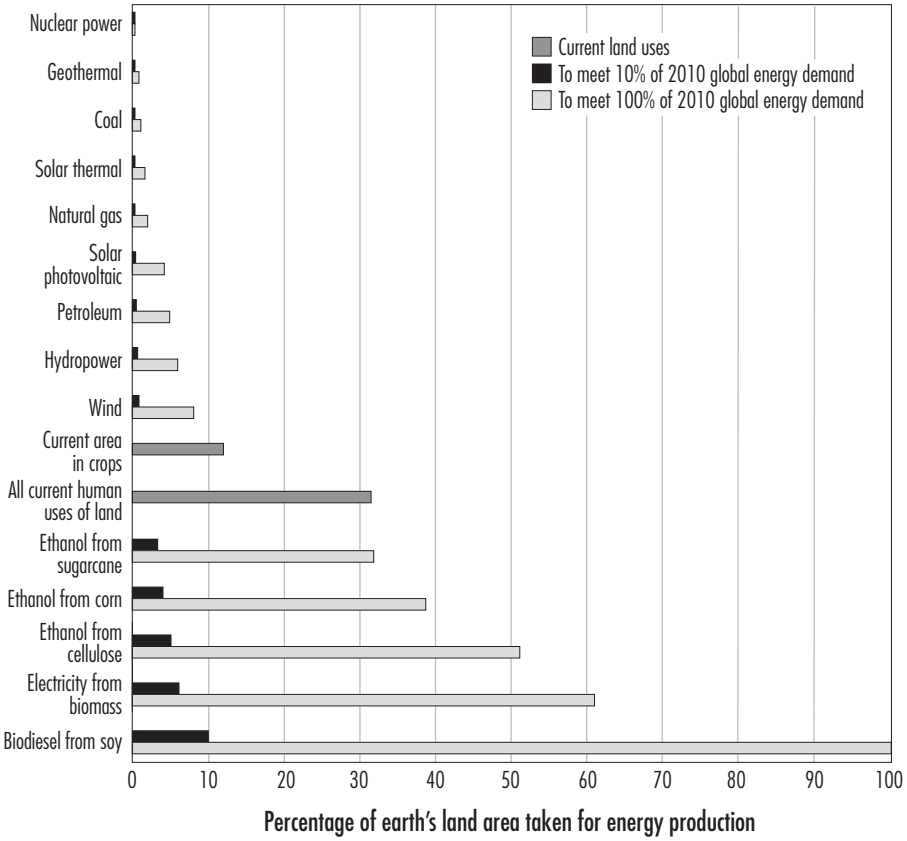
"There is a critical link between the way that governments and industry respond to these social and environmental challenges and the prospects for unconventional gas production," writes the IEA in its Golden Rules Report.

Land use

One of the major objections to shale gas drilling is the room it takes up and the impact it has on the land around it, through increased traffic and other activity. Unlike conventional reservoirs, unconventional reservoirs have large areal extent, and to produce from such a wide geographical area requires drilling a large number of wells to achieve extensive reservoir contact.

Nevertheless, when it is compared to alternative sources of energy such as wind, it still uses just a fraction of their requirement. The power density of wind energy is 1.2 W/m2, and solar photovoltaic about 6.7 W/m2. A marginal natural gas well, producing 60,000 cubic feet per day, has a power density of about 28 W/m2, according to expert Robert Bryce of the Manhattan Institute. Add to this the intermittent nature of renewables, and the comparison is worse still.

Land requirements of alternative energy sources



Sources: Land intensiveness data from McDonald et al. (2009); land area data from Melillo et al. (2009); global energy demand data from EIA (2009a)

Land use is an area where technology can make a difference, reducing land requirements and impact even further. In heavily populated China, for example, Shell has already cut the amount of land it needs for each shale gas well by 35 percent. Better directional drilling techniques mean wells can be drilled from more convenient sites, and other advances mean more wells can be drilled from a single pad.

The chart above shows how much land would be required for each energy source to supply both 10 percent and 100 percent of the world's current energy demand.

Water use

Unlike conventional gas projects, where the resource is drawn from a reservoir relatively easily, unconventional gas must be extracted from tightly-packed, brittle sedimentary shale. That has so far required millions of litres of fluid, usually water, mixed with chemicals and sand and injected underground, putting pressure into subsurface fractures so the gas can flow toward the surface.

Water use by the unconventional gas sector varies according to each location and operation, but according to the Canadian Society for Unconventional Resources (CSUR), a typical fracking operation might use 20,000 cubic metres of water as its primary fracturing fluid for a relatively small section of a fracking operation – a significant burden on any water system.

The problem is particularly acute in areas with limited water supply, such as west Texas and, more recently, China. With such a huge potential to unlock in China, many developers are involved in producing innovative products that will reduce the amount of water used, facilitate the use of salt water and even replace it altogether. In Texas, considerable progress has already been made, particularly in the use of treatment facilities that allow the use of brackish water and the recycling of well fluids.

The impact of shale drilling on water resources is very real and substantial, but it is one of the main areas where technology can address the challenges and make a substantial difference.

Ground water

While there may be a perceived risk, theory suggests that at the depth fracking is normally carried out, there is little risk to drinking water systems, which are at much shallower depths. Scientific studies are beginning to confirm this. For example, a landmark US federal study on hydraulic fracturing by the National Energy Technology Laboratory in Pittsburgh7 and cited by the US DOE, showed no evidence that chemicals from the natural gas drilling process moved up to contaminate drinking water aquifers at a western Pennsylvania drilling site.

After a year of monitoring, the researchers found that the chemical-laced fluids used to free gas trapped deep below the surface stayed thousands of feet below the shallower areas

that supply drinking water. The study marked the first time that special tracers were injected into fracking fluid, which were monitored to see whether they spread toward drinking water sources.

Drilling fluids tagged with unique markers were injected more than 8,000 feet below the surface at the gas well bore but weren't detected in a monitoring zone at a depth of 5,000 feet. The researchers also tracked the maximum extent of the man-made fractures, and all were at least 6,000 feet below the surface.

That means the potentially dangerous substances stayed about a mile away from surface drinking water supplies, which are usually at depths of less than 1500 feet. Nevertheless, removing all toxicity is preferable, and achievable with upcoming technology. While fracking fluids may stay well below drinking water aquifers, drillers still have to cope with a 6 percent failure rate on well bore casings, according to a recent study by Duke Energy10.

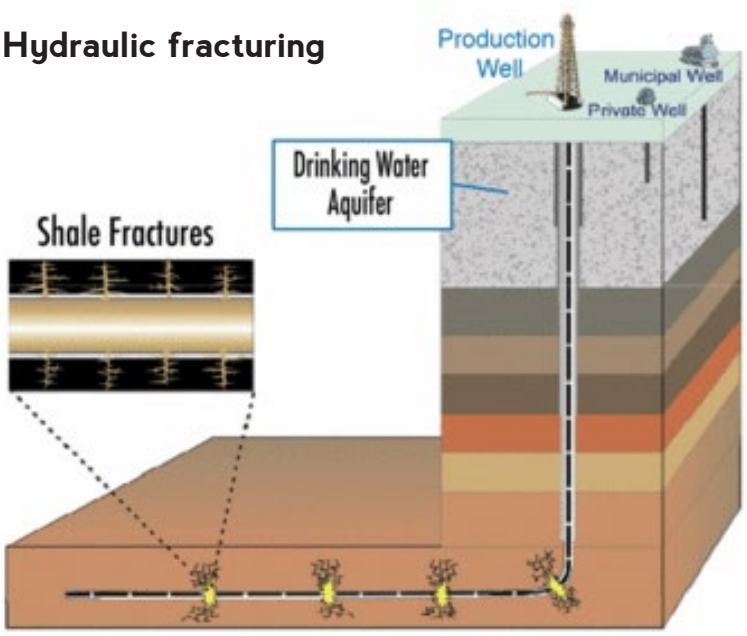
Surface pollution (air and water)

Contamination of surface water and air with methane is an area of concern. But a recent study by the University of Texas8 concluded that methane emissions from shale gas wells were significantly lower than previously thought. And, in general, the latest US academic research into air and water pollution from shale drilling generally shows air pollution is more of a threat than water pollution, while the huge processing stations that push gas into US national pipelines could actually may be more of a problem than the drilling sites themselves.

The biggest air pollution challenge is to reduce natural gas leakage from the well bore – or as research appears to be indicating, gas processing plants. Methane is a far more powerful green-house gas than carbon dioxide, so any release of methane during drilling or production undermines the fuel's green credentials, eroding its CO_2 emissions advantage over coal.

As far as water contamination is concerned, the mix of chemicals used in fracking varies by company and region, and while some are openly listed the industry has complained that disclosing special formulas could violate trade secrets. Some of the chemicals are toxic and could cause health problems in significant doses, so the lack of full transparency in some US states has worried landowners and public health experts.

Hydraulic fracturing



Source: IEA

While technology can be applied to tackle the problem, it is operational practises and routine aspects of the drilling process that are most likely to cause problems in this area. This can be avoided by adhering to strict procedures designed to avoid accidents and environmental contamination. Sloppy well construction that allows excess gas to escape, spills of chemicals or other fluids that pollute the surface, and failure to clean and dispose of wastewater are all issues of concern.

Another study, dubbed the Southwest Pennsylvania Environmental Health Project9, has been monitoring possible long term drilling-related health impacts, but most of the problems that researchers have seen have been related to well construction, not fracking chemicals.

Seismic impact

Earth tremors tend to occur as waste water is re-injected into deep wells, rather than as part of the actual fracking activity itself. While no earth tremor is welcome, the level of seismicity is comparable with coal mining or the impact of filling a reservoir, which tend to have rather more effect on the tensions that build up in the earth's crust than fracking or even deep disposal of fracking waste water.

Technology in the area is aimed at improving monitoring and evasive action. Fault lines should be avoided, and if development causes heavier than usual seismic activity, then drillers should be prepared to abandon some wells.

The monitoring through micro-seismic technology (which were originally used to detect seismic activity around coal and other mines) involves lowering detectors into a listening well near a fracked well. Once the well has been drilled, the seismic devices pick up the noise of where the rocks are breaking, and triangulates the sounds to map out the rest of the play. Monitoring tends to be carried out as an integral part of any development to help decide where best to drill next, so while regulations are appropriate, they may not be necessary. The same monitoring can watch for the danger signals of stress release within fractures, stopping development – as was the case in the UK in 2012 – if any danger signs are detected.

ADDRESSING THE RISKS AND OBJECTIONS

Janez Potočnik, European Commissioner for the Environment

"Companies active in the EU already comply with national and EU environmental regulations which generally are more restrictive than on the other side of the Atlantic, so they guarantee higher safety levels," says Jacek Krawiec, CEO of PKN Orlen.

In Europe it is clear that regulations are already tougher than in most of the US, and they are likely to get tougher still as legislation emerges from Brussels. But few developers would object to tough regulations, as social acceptance is widely acknowledged to be an essential prerequisite for development in Europe and many other regions, and that can only be gained (if at all) by adhering to the highest possible standards.

"As an industry, we tend to get our hackles raised as folks who want to simply kill the oil and gas industry altogether push for more and more regulations, but we also accept these as the cost of doing business and we understand that tough regulation can have the additional effect of helping to calm the fears of residents in the regions where we operate," says Chris Faulkner, CEO of Breitling Energy.

"[We must set] clear rules for investors, then decisions are for them… Having social acceptability for [shale gas development] is the most important thing"

— Janez Potocnik, EU Environment Commissioner

Europe Struggles with Social Acceptability

"Europe subsidises technologies endorsed as being 'right'. In this atmosphere, there can be no revolution in energy… when it is more profitable to invest in whatever is already enjoying the financial support of the authorities," says Krawiec.

Of all the obstacles to shale gas development in Europe the most daunting is without doubt social opposition, highlighted in August by the mass protests at Balcombe in the UK, and on a more local scale in Romania in late October. This social concern over fracking is heavily reflected in the European Commission, where many critics claim policymakers focus far too closely on potential risks at the expense of any consideration of the benefits.

PKN Orlen says: "EU officials should not be afraid of shale gas, since benefits are huge and risks are minimal, but no-one wants to admit this…. Several EU countries invested heavily in green technology, others in nuclear energy, and they are concerned shale gas would be more competitive. EDF has already had to quit its 3.9 GW US nuclear

business, which cannot compete with cheaper and safer natural gas based energy."

Reinforcing the emphasis on risk, the European Parliament backed mandatory environmental impact assessments (IEAs) for hydraulic fracturing in a close vote in October. Jose Delbeke, director general of the Commission's climate action department, said that mandatory testing for methane leaks at sites would also have to be introduced.

Some member states are opposed to EIAs, including UK and Poland, while some energy companies have complained that extra bureaucratic processes will stifle shale gas exploration with no environmental benefit.

As a compromise, MEPs backed a proposal in which EIAs would be required for shale gas extraction but not for initial exploration, so it would only apply once companies begin using hydraulic fracturing for tests.

Janez Potočnik, the European commissioner for the environment, said after the vote that the Commission would carefully examine the proposed amendments. The European Commission is currently preparing a policy proposal dedicated to shale gas, which is expected before the end of the year. It is still unclear whether this proposal will be new EU legislation or guidance.

Clear EU rules

In an interview for this report Potočnik emphasized that it was not for the EU to decide on whether or not to develop shale gas, but in the hands of member states and investors. His role was to set out clear rules, which would help the industry gain social acceptance:

"We need to ensure that any investor in Europe has long term predictable rules in place, and that all citizens can rest assured that any industrial activity – fracking or any other – won't hurt the environment… and we have to decide the best way to do it," the Commissioner said.

When questioned about the importance of shale gas development in the EU's strategy of reindustrialisation, he said it was best to concentrate on minimising resource needs:

"We are a densely populated area, which is locked in resource intensive production be it in economic structure, business structure or financial models, and we are living in a decade when resource prices are rocketing. I think the figures are that between 1998 and 2011 there was a 300% resource cost increase, and markets are also volatile. This is becoming serious competitive issue, for example data from German industry shows the current cost structure to be 18% labour and 43% resources - we talk about labour market flexibility but not much about resources, and we are import dependent – more than 60% for energy as a whole…. all this is pointing you towards producing products using less energy, less water and resources, more efficiently, recycling and reusing," he said.

Companies active in the EU already comply with national and EU environmental regulations which generally are more restrictive than on the other side of the Atlantic, so they guarantee higher safety levels."

—Jacek Krawiec, CEO of PKN Orlen

Do you think shale gas could bring down costs in Europe?

"We know what is happening in the US, but we don't know if that is longer term or shorter, but we know that when you talk on prices you can't compare the US with Europe. Here the extraction is more costly, longer term contracts and so on… if it fits in with the strategy of the country to progress to low carbon economy, that's for them to decide… [We must set] clear rules for investors, then decisions are for them… Having social acceptability for [shale gas development] is the most important thing, and having clear rules is necessary for social acceptability, and this is also in the interests of any potential investor. It is important to tackle social acceptability head on - better we don't create rules before an event like [Macondo in the US Gulf] than after," Potočnik said.

Are Strict Rules enough for Social Acceptance in Europe?

But are strict rules sufficient to gain social acceptance in Europe? The shale-gas debate is highly polarized, with many opposing it on ideological grounds. Anecdotal evidence and emotional rhetoric often takes the place of sound scientific evidence. Worse still, many people have already made up their minds without understanding the issue.

This is illustrated by the result of a recent EU consultation, which showed that only 15% of individuals and a just 10% of the organisations that took part declared that they would be ready to change their opinion about shale gas. Another 15–20% said "maybe", while the overwhelming majority ruled it out completely. At the same time respondents said insufficient information was a major problem in the European debate - so most interested parties have made their minds up while ignorant of the facts.

We put these issues to Maria Van der Hoeven, Executive Director of the IEA, in an interview for this report.

What advice would you give EU on shale gas?

"Europe's unconventional gas resources are large but in practice the push to develop them varies considerably by country, depending on the mix of domestic fuels and important and perceptions of the risks to energy security and the environment. There are good reasons for Europe to consider this resource: the EU has the second-largest regional gas market in the world, with growing dependence on imports, with well-established pipeline/storage networks and relatively high natural gas prices. But there are above-ground factors that are likely to impede rapid growth, chief among which is the high population density in many of the prospective areas. Poland is something of an exception in this regard.

Moreover, developing a sizeable shale gas industry takes time (it took about 8 years in the US and it is not going to be faster in Europe). Although we do not expect any significant shale gas production in Europe before 2020, Poland has started down this path, and will be there first. Other countries will come later," said Van der Hoeven.

Is the US shale gas boom sustainable and can the shale energy revolution be exported?

"I do not think the US experience can be copied and pasted, but in general the answer to both questions is yes, provided that producers have a social license to operate. Let me explain what I mean: The technology and the know-how already exist for unconventional gas to be produced in an environmentally acceptable way - but if the social and environmental impacts are not addressed properly, there is a very real possibility that public opposition to drilling for shale gas and other types of unconventional gas will halt the unconventional gas revolution in its tracks.

The industry must win public confidence by demonstrating exemplary performance; governments must ensure that appropriate policies and regulatory regimes are in place. For this to happen, the so-called "Golden Rules" must be applied. We detailed these in a publication we issued in 2012: Golden Rules for a Golden Age of Gas.

In response to the strong support for the Golden Rules from governments, industry, NGOs and other key stakeholders, the IEA decided to build upon the golden rules by establishing an IEA Unconventional Gas Forum. The forum aims to enable governments around the globe to share insights, alongside input from industry and other key stakeholders, on operational best practices and regulatory action towards securing the economic, security and other benefits of increasing unconventional gas output," Van der Hoeven said.

Jacek Krawiec, CEO of PKN Orlen

"The EU has the second-largest regional gas market in the world, with growing dependence on imports, with well-established pipeline/storage networks and relatively high natural gas prices."

— Maria van der Hoeven, Executive Director, IEA

PKN Orlen says: "In Poland, there is a high level of public support for the exploration and extraction of shale gas [because our people understand the benefits it could bring]… As a country, we are also aware of the fact that EU policy on greenhouse gas emissions means coal-based energy will become more and more cost ineffective. Therefore, as a member of the EU community, we should expect legislation that will enable us to develop innovative technologies such as shale gas."

EU Energy Policy lacking as European Industry Faces the wall

While European bureaucrats focus on risks and a single market, European utilities and industry are facing a growing competitive disadvantage in energy costs compared with North America, where shale gas has sent prices tumbling. The situation should be serious enough to focus the minds of European policy makers.

"European policy makers must ask themselves why any investor would want to expand in a market with such high energy costs when across the Atlantic they are so much lower, along with all the other advantages of the US," says Eni CEO Paolo Scaroni.

If the EU is to meet its commitment to strengthen its industrial base by increasing the share of industry in overall GDP from 15 to 20 percent by 2020, something needs to be done about energy costs quickly, and energy and climate policies need to be reworked to transform them into true industrial growth drivers. Germany's BDI has called for Europe to diversify its energy supplies and be more positive towards shale gas, while combining climate action with cost efficiency by reviving the Emissions Trading Scheme as a mechanism to reduce industrial emissions across Europe.

The head of Eon, Germany's largest utility, Johannes Teyssen, said recently that the widening gap between US and European energy costs could lead to a mass exodus of energy intensive industry across the Atlantic. Even if Europe put aside its environmental concerns and decided to pursue fracking aggressively, it would take at least five years to develop such an industry, he predicted. But increasing gas supply from shale would relieve distortion in the market caused by generous subsidies for renewable energy, which have forced Eon to mothball gas-fired plants that are efficient but no longer profitable.

"It is necessary to develop European know-how that will adapt [fracking] technology to local conditions. It will not happen, however, without a clear signal from the European Union and without the creation of business and legislation environment favourable to conduct shale gas related R&D initiatives," says PKN Orlen.

Given Europe's lukewarm reaction to shale gas, very few big oil and gas producers are braving the market. Speaking at the FT Shale Energy conference in October, Mr Scaroni of Eni said that his company would not be exploring for shale in Europe because it would rather get on with the job than talk, and in Europe there "would be months of talking." "Continental Europe is not right for shale gas today", he said, although he did not rule out the UK, where rival GdF Suez has just farmed

in to a number of licenses held by Dart Energy.

"With North Sea reserves on the decline, the UK's unconventional reserves could not only pick up the slack but give it an American-style energy boom that would stabilize the economy and energy prices for many years to come," says Chris Faulkner, CEO of Breitling Energy.

IEA Golden Rules

"The IEA's Golden Rules are a good start as a framework for [European Union regulation], we are pretty well inside that," Commissioner Potočnik said.

As a guide for its members, the IEA has developed a set of "Golden Rules", suggesting principles that can allow policymakers, regulators, operators and others to address environmental and social impacts.

Their application is designed to bring a level of environmental performance and public acceptance that can maintain or earn the industry a "social licence to operate" within a given jurisdiction, paving the way for the widespread development. As the IEA puts it in the report: "A continuous drive from governments and industry to improve performance is required if public confidence is to be maintained or earned. The industry needs to commit to apply the highest practicable environmental and social standards at all stages of the development process."

The Golden Rules underline that full transparency, measuring and monitoring of environmental impacts and engagement with local communities are critical to addressing public concerns. Careful choice of drilling sites can reduce the above-ground impacts and most effectively target the productive areas, while minimising any risk of earthquakes or of fluids passing between geological strata.

Leaks from wells into aquifers can be prevented by high standards of well design, construction and integrity testing. Rigorous assessment and monitoring of water requirements and of waste water can ensure informed and stringent decisions about water handling and disposal. Production-related emissions of local pollutants and greenhouse-gas emissions can be reduced by investments to eliminate venting and flaring during the well-completion phase.

The IEA estimates that applying the Golden Rules could increase the overall financial cost of development a typical shale-gas well by an estimated 7%. However, for a larger development project with multiple wells, additional investment in measures to mitigate environmental impacts may be offset by lower operating costs. Other organisations, including commercial ones such as DNV, have also developed standards. Speaking to us for this report DNV's CEO Remi Eriksen, said its rules could be used as a basis for worldwide regulation; based on its extensive experience in setting maritime standards.

"The IEA's Golden Rules are a good start as a framework for [European Union regulation], we are pretty well inside that."

— Janez Potocnik, EU Environment Commissioner

A view from the European Parliament

We spoke to Polish MEP Bogusław Sonik (EPP) , and asked him if he believes the European Commission is approaching the shale gas opportunity in the right way: "I'm afraid that in certain areas the European Commission, in particular DG Environment, excessively emphasizes the negative impact of shale gas extraction on the environment. It is also likely that, without taking into account the voice of shale gas supporters, the Commission will soon announce that the tightening of European regulations on shale gas is necessary. Let me remind you that till the 25th of March, the European Commission held public consultations; everyone could fill out a survey giving their view on shale gas: its impact on the environment, opportunities and threats. I must admit that from the very beginning, the wording of the questions caused doubts. The questions were biased and were suggesting that there are generally negative consequences of the exploitation of shale gas. What made this consultation even more controversial were the results published by the European Commission. Even though more than 60% of respondents were in favour of shale gas exploration in Europe, the European Commission applied a controversial weighting system based on the Member States population, which changed the actual results. The weighing system shaped the Commission's final report which presented negative attitude of citizens towards shale gas. Several MEPs, mostly Polish, as we were the biggest group of respondents, found the weighting measures biased and the presented results unacceptable. Speaking of the Commission's attitude I would also like to underline that there have already been 46 wells drilled in Poland. Unfortunately, the experience gained from developing these wells, as well as the results of the environmental analysis were never taken into consideration by the European Commission. I have tried to point this out to them with a parliamentary question, but with no result. The European Parliament's attitude towards shale gas is also rather cautious. According to a recent vote, any future exploration and exploitation of all nonconventional hydrocarbons, including shale gas and oil, as well as coal gas, should be subject to a mandatory environmental impact assessment. The result of the vote was tight. A certain coalition including Polish, British and German MEPs was created. These MEPs explicitly criticized the outcome of the EIA vote. In our opinion, if the new environmental regulations will come into effect, especially the mandatory assessment at the stage of exploration, there will be a significant delay in the development of shale gas industry in the EU member states. It is important to notice though that the positions within the Parliament are polarised. When it comes to shale gas the MEPs are divided. Until now the final outcome was usually in favour of the development of shale gas industry in Europe. However, the last vote on the EIA breaks this trend."

Californian Standards

While standards in the US are thought insufficient by most in Europe, they are set on a state-by-state basis, and California passed its first bill regulating fracking in September, with rules more along the lines expected in Europe. The bill was opposed by both environmentalists and oil companies. The former want an outright ban on fracking, while the latter believe the bill could make it difficult to conduct fracking operations. Considerable opposition exists to the development of the onshore Monterey shale in California, given uncertainty over what impact fracking could have on the seismically active region.

Under the bill, companies would be required to obtain permits for fracking as well as for use of chemicals in fracking fluid. The bill would also require notifying neighbours, public disclosure of chemicals used, groundwater and air quality monitoring and an independent scientific study. The US government has tightened regulations for offshore shale drilling, which had taken place without much scrutiny until the Macondo disaster in 2011.

Aside from California, many states continue to have minimal regulations while some maintain moratoria. Upstate New York is currently a focus for the debate, where the state imposed a temporary moratorium on fracking in 2008, and has been waiting for additional studies from state and health agencies before deciding whether to let it proceed.

The Ability of Technology to address Issues Raised by Shale Gas Development

Technology is already capable of addressing many of the environmental issues raised by shale gas development, and as companies look to produce gas from more densely populated, environmentally sensitive and water-poor regions of the world, new products and techniques are being developed to ensure as little impact on the environment as possible.

"I think most of the technical innovation will be on the surface, for example the way you treat water, the number of wells from each pad and maximising the recovery rates. Getting more out of each well is important, as you then have to drill fewer wells. Steep depletion rates for each well will be a target for technology," says Remi Eriksen CEO of DNV.

Reduction of Water Use

"Well integrity is important but water is the key. Anything you can do to reduce water use will take the pressure away on the environmental side,"said Lars Sorum, Director Unconventional Gas at DNV.

In developing shale gas, water use has perhaps the biggest environmental impact, while management of the water can involve significant cost and effort. Therefore reducing that use or widening the type of water that can be used to include brackish or flow-back water, has an enormous impact on a fracking operation's environmental footprint.

Those interviewed for this report largely agreed that this area had the most potential for major technological improvements in the near term, helping the development of fracking particularly in water constrained regions such as China, South Africa and west Texas. If developments come forward as planned there will be less need to set up regulations in the area, as costs will be cut as much as environmental impact.

Technology can also cut the use of chemicals such as those added in slick-water fracking. Known as water 'friction reducers', they allow for more efficient gas extraction, by allowing fluid to be pumped down the well-bore far more quickly. They also enable extraction in highly pressurized, deeper shales. The technology cut fracking costs by three quarters in the late 90s, but new advances could make their use redundant.

"Any company producing technology that is more environmentally friendly, from the water point of view or use of chemicals, seismic, is, of course, welcome in Europe," said EU Environment Commissioner Janez Potočnik.

Hydraulic Fracking Fluids and the Story of Guar

Critical to hydraulic fracturing is the drilling fluid, of which the most important element is the gellant, followed by the proppant, along with a liquid medium, normally water.

Gellants have traditionally been based on the organic guar bean produced mainly in India and Pakistan. Adding guar bean powder, also known as guar gum, to water increases its viscosity and makes high-pressure pumping and the hydraulic fracturing process more efficient.

High viscosity fluid is needed because it improves the penetration of the tiny grains that make up the proppant, which are carried deep into the rock by the sudden rush

of water that accompanies the opening of fractures in the fracking process.

When the pumps are turned off water pressure within the fractures drops and they close suddenly. If enough proppants have been carried into the fractures they prevent them from closing completely. These partially-closed fractures then become passageways that allow oil and natural gas to flow out of the rock and into the well.

Guar or cluster beans, have been cultivated in north-western India and Pakistan for many centuries. It is an annual legume that grows well in a variety of soil types and in arid to semiarid climates, and has recently been widely planted in Texas. However, like any crop, supply is subject to the vagaries of the weather, and as a commodity, prices can vary wildly.

In addition, chemicals must be used to prevent bacteria from growing in the guar, which is organic, and attractive to bacterial contamination. So although guar is a natural product, its use often requires artificial additives.

Use of synthetic gellants removes the need for anti-bacterial agents, and can cut the impact of drilling on the environment, for example by reducing water use. Guar also needs relatively fresh water to work properly, while synthetic gellants can cope with a wider range of impurities. They can also ensure more gas is recovered, and can be used in more extreme conditions, improving the efficiency and performance of shale gas recovery.

Synthetic Gellants

Guar can be replaced by synthetic gellants. Oilfield service companies and independent chemical companies are leaders in this field. “Technology is much more in the hands of service companies than [majors]”, said Mr Scaroni of Eni.

For example, Frankfurt-based technology company TouGas Oilfield Solutions has produced a range of gellant products that can use wastewater already available at well sites. These products entirely eliminate the need to use fresh water in fracking and therefore enable fracking in water constraint regions. In addition, the TouGas Oilfield Solutions products lead to ‘green’ frac fluids by eliminating the use of biocides and other additives, so that the most demanding future regulatory requirements can be met.

“Water critical issue especially down in South Africa. Anything that reduces water requirements is a step forward, because South Africa has put the brakes on waiting to see if the new technology required [to cut water requirements] is out there, because South Africa is an extremely water scarce area. They are concerned about the large volumes of water currently involved in fracking,” said Kurt Lonsway, Acting Director of Energy, Environment and Climate Change at the African Development Bank.

The TouGas Oilfield Solutions gellants also allow fracking to take place at much higher temperatures, which will permit development of the deeper shale deposits that occur in China and elsewhere. Temperature tolerance of up to 230C also makes fracking possible at high-temperature, high-pressure wells in Eastern Europe and the Gulf of Mexico using such fluids, illustrating the way new technology steadily expands the recoverable reserve base.

TouGas Oilfield Solutions gellants are manufactured under patent using a flexible and low cost technology. All properties of the gellants are patentable, and TouGas Oilfield Solutions currently has six patents filed and two already granted. The intellectual property is the result of several years’ work by an experienced industrial team in the heart of Germany. It has plans to expand research into China, to target the particular challenges of shale rock in that energy hungry and water poor nation.

The pace of innovation is far more rapid than in hardware or engineering, where new drilling technologies can take up to 10 years to be embraced - while new gellants and other chemicals

Tore Land, CEO, TouGas Oilfield Solutions

“TouGas Oilfield Solutions has produced a range of gellant products that can use wastewater already available at well sites. These products entirely eliminate the need to use fresh water in fracking.”

are introduced and accepted within 6 to 18 months. The heart of oil and gas innovation is currently in the materials and chemicals industry, driven by dynamic international technology leaders like TouGas Oilfield Solutions.

TouGas Oilfield Solutions' synthetic gellants will reduce the impact of fracking in areas short of water, of which Texas has the most mature unconventional hydrocarbon sector, by cutting use and facilitating the use of salt and brackish water. A recent study on water use for fracking by the University of Texas found that between 30 percent and 3 percent of the water used in fracking in Texas was brackish in 2011, a figure that is expected to rise sharply, reducing pressure on fresh water resources in a state suffering from the worst drought since the 1950s.

Other companies are experimenting with saline water found in deep aquifers in British Columbia's Horn River Basin, where there are a lot of identified saline aquifers. Using them would mean the fracking operations do not compete for fresh water with farmers, cities and towns. However, use of such water raises further questions, including what to do with it after use, and how to reduce the cost of the treatment it requires before fracking.

In an interview for this report, Chris Faulkner, award-winning CEO of Breitling Energy*, said the recycling and re-using end of shale oil and gas production was currently a hotspot for innovation. Examples include waste water equipment manufacturer Ecologix, which "has partnered with General Electric on two methods of recycling waste water, one to recycle the wastewater by using a separation technique, and another using a water-cleaning boiler system."

"Fountain Quail Water Management, has developed a new technology for first producing a briny water by removing everything but the salt from flowback water, and then distilling the briny water for re-use in fracking. ThermoEnergy has also created an application for recovering contaminated flowback water and recycling it into clean water. ThermoEnergy's technology also concentrate's the chemicals and other impurities for safer recycling or disposal," said Chris Faulkner, CEO of Breitling.

**Chris Faulkner CEO of U.S.-based Breitling Energy Corporation, has been named an Industry Leader of the Year finalist by the prestigious Oil & Gas Awards. His company is also a finalist in the categories of Exploration and Production and Corporate Social Responsibility.*

Problems with Treatment

Synthetic gellants like those produced by TouGas Oilfield Solutions, help avoid the need for heavy water use and treatment. Other fracking fluid technology companies have concentrated on recycling and used water quality. Such treatment requires heavy up-front costs, changing the cost structure of the fracking process. Flow back management must deal with highly variable volumes, with a lot of water at the beginning, tailing off to a small amount over several weeks. So any attempt to clean up using mechanical methods faces major logistical challenges, as well as more land use and energy for storage, power and clean up.

Power access for membrane clean up facilities can also be problematic. As regulations are increasingly imposed, existing techniques based on 'clean up after the fact' technologies will be imposed, which all require more land use, power and so on – creating a regulators' paradox where safeguards and restrictions result in greater environmental impact, not to mention an increased cost burden. Some companies, such as Trican Well Service Ltd., have developed fracking fluids that can be classified as non-toxic, and although there are still chemicals that need to be recovered, they are not classified as a threat to water quality, so the used water is easier to treat and restore.

With water reduction, and use of dirty water, these problems are avoided. Such technology can be a game-changer especially where water supply is limited such as China – here some drillers are mobilizing rigs for fracking in areas where it was not viable before, on the basis of new gellants like that of TouGas Oilfield Solutions. The developer believes it can steal a major advantage over competitors in China by using the technology, which could be a promising sign of an emerging competitive market among shale developers – it is the right time for whoever gets in there now with such an advantage, the prize is enormous.

Douglas Uchihara of Chevron said: "Technology is a function of scale and we are fortunate in Europe that the US has provided the scale. The whole discussion about developing fracking with less water and so on, can now take place."

Alternatives to Water Use

Heavy water use has been such a major factor in the early stages of shale gas development that a whole range of solutions have been proposed, including products that eliminate the need for water completely. Chevron and eCORP International with GasFrac Energy Services are a couple of companies looking at propane-based technology, according to Mr Faulkner. A propane-based gel is injected into subsurface fractures at its acreage – mostly in the Canadian basin - in the same way as water-based fluids are used.

The propane acts in two ways. Propane has a surface tension about a tenth that of water, which allows the fluid to slip more easily into the tinier fissures of a fracking operation, helping to open the cracks more, to get at more gas and help it flow out. Propane also has lower viscosity and density, so it dissolves more easily in the cracks and distributes more all along the fracking lines, leaving less chance for the proppant to get jammed into micro-cracks, so the gas will flow. Mr Faulkner notes the obvious drawback is the flammability of the propane gel, "but that's another thing eCORP is working to solve, and the advantages still make it a really attractive and enticing prospect", he said.

"Aside from the obvious advantage of minimal water usage, propane gel is exciting because it mixes with petroleum and returns to the surface with the extracted oil and gas without dissolving salts, heavy metals or radioactive compounds like water does, eliminating the worry of these pollutants returning to the surface in the flowback," said Breitling's Faulkner.

The ability to turn propane into a gel and inject it under high pressure is leading-edge technology that's already proving

itself, helped by a number of factors, not least computer power according to the product's developer – something that is constantly accelerating and is sure to keep technological innovation on the boil. Carbon dioxide can also be used as an alternative to water, according to Lars Sorum: "There are a number of research projects going on, one of which is assessing whether CO_2 can be used [as a replacement for water]. Carbon dioxide can be used as a fracking fluid, and can also be injected as a foam for enhanced recovery programs offshore… The problem with this option is that there is not enough carbon dioxide available; it is difficult to get hold of."

In addition, there can be fresh complications when adopting such major changes: "With completely new techniques like CO_2, you may get new issues, corrosion for example, which may mean you need to use more chemicals than you did with water. The problem with addressing risks is that you create other risks with the precautions put in place," he said.

"Carbon dioxide fracking is another method showing promise, requiring about one-tenth of the water typically needed for fracking. Carbon dioxide is a more re-usable resource than water, with most of it coming back out of the well for capture and recycling. Since most of the carbon dioxide returns to the surface, production flow is better. What carbon dioxide remains in the shale can be sealed up underground once the well is done producing, reducing greenhouse gas emissions. The main limitation for carbon dioxide fracking at the moment is lack of infrastructure. In states like Wyoming, which already have carbon dioxide pipelines, operators can take full advantage of this alternative to high volumes of water," Chris Faulkner said.

Proppants

Sand and sand-based materials became the most popular type of proppant due to availability and low cost. Research is on-going into proppant with higher strength, lower weight and better transport ability. This is coupled with new injection schemes that enabling better proppant placement, which increases production from each well. This means more energy produced with less surface impact, and could reduce the volume of fluid required.

Schlumberger has developed a method for improving flow and increasing flow duration by adding fibers to the frac mix, to hold open the cracks in the shale, according to Mr Faulkner. And some companies, such as Carbo Ceramics, have developed ceramic proppants which they claim adds strength while ensuring a uniform size and shape. This is designed to provide higher performance, with improved production of oil and gas in a variety of reservoir conditions.

But, compared to gellants, it was generally felt there would be no game-changing proppant improvements, sufficient to have a major impact on cost or environment. Remi Eriksen of DNV summed up the feedback: "Proppant is basically silica sand and that's not going to change very much."

Release of Methane and Well Fluids

"Methane is the product, so, while there is an environmental need to contain raw methane, there's also a very strong business need to capture all of it. Work in this area isn't as exciting as innovations in fracking fluids and methods, but it's ongoing in the form of mechanical maintenance, use of better gaskets, and improved monitoring," said Faulkner.

Innovation in regulation and services can be just as critical as innovation in hardware. Guarding against fluid release is partly dependent on the technology and quality of well casing and other hardware, but most contributors to this report felt this to be more of an issue of appropriate regulation and close observation of rules. As the IEA states in its Golden Rules report: "The technologies and know-how exist for unconventional gas to be produced in a way that satisfactorily meets the challenges."

Speaking in an interview for this report Remi Eriksen, CEO of DNV, said new technology would help in coping with potential methane slippages when drilling. But, on the whole, the release of surface pollutants associated with well casing integrity was seen by many contributors as primarily an operational issue, dependent on close observation of procedures necessary to conform to suitable regulations, and ensure risk free operation.

According to Lars Sorem of DNV: "There is no straight answer [technological fix for fluid release], even with technology available now companies are fully capable of doing things without incident if they follow the right operational procedures safely and sustainably. Returns (used water) coming back should be treated – this will not bring down cost, but can demonstrate that you have the operation under control. [Preventing surface air and water contamination] is more an operational issue than one of technology, although using the best technology helps make operating easier."

Remi Eriksen added: "You have to monitor what you are doing, to see if you are doing what you have committed to." Turning the emphasis away from technology, he explained that innovation was also needed in regulation and standards. "Innovation in regulation is required to ensure the best standards are achieved and applied effectively. The regulations must also innovate to ensure public satisfaction."

DNV has long been involved with marine standards, and represents a private commercial alternative to national or regional hydraulic fracturing standards. It is already a global provider of services for managing risk, combing risk methodology, technology expertise and in-depth industry knowledge to enable customers to safely and responsibly improve their business performance. It identifies, assesses and advises on risk management and performs independent assessment and verification. DNV has published a Recommended Practice document for shale gas operators.

DNV say it can help operators demonstrate that they operate safely and sustainably by providing independent assessments of their operations, measured against regulations, standards and best practices.

Cost Reduction and Enhanced Recovery rates

"Another challenge [for shale wells] is recovery rates, which are much lower than in conventional wells. So there I would expect to see higher recoverability due to improved

technology over the years. However, improvements in directional drilling and recovery rates will be achieved incrementally, rather than with any game changing advances – most of the innovation has been done in horizontal drilling and injection already. Although compared to conventional drilling, there is less return per well with shale so less incentive to maximise extraction," said Remi Eriksen, CEO DNV.

In the US, the characteristics of the various shale plays are known, and developers - under pressure from falling gas prices - have been focusing on bringing down costs and the economics of development. There's already a lot of movement toward centralizing drill operations, which allows operators to exert tighter controls over digging and fracking, as well as improve containment of gas emissions and wastewater, by consolidating multiple well operations in a single site. The speed, cost and extent of wells has been improved dramatically over the last ten years.

Drilling multiple branched wells rather than a single horizontal well may also help target previously un-stimulated areas of shale rock identified by combining micro-seismic, 3-D seismic and flow data from individual perforation clusters. Recovery rates depend on the current state of technology, and with shale gas that is generally up to a maximum of 15% at the moment - which leaves tremendous room for growth as technology improves.

Drilling in the right spot is key to extracting the maximum. Because shale is not homogeneous, targeting the part of the shale with the largest resource is critically important. Advances in drilling with rotary steerable assemblies, diamond crystalline bits and logging are allowing the steering of wells to target the spot with the best hydrocarbon potential and best fracture ability.

Halliburton is a leading provider of such technology, and its new CYPHERSM Seismic-to-Stimulation Service is among the most advanced products to help optimize productivity and well economics. The product involves detailed geoscience earth modelling, integrated with drilling and completion engineering processes.

Shale and tight reservoirs can contain multiple sweet spots mixed with non-productive rock. Misplaced fracturing zones or missed production opportunities can result in expensive wells and sub-optimized well economics. Cumulative production can vary widely in a field, depending on well placement. In Texas' Eagle Ford, for example, one operator gained a four-fold increase in cumulative production and reduced drilling costs by increasing the accuracy of wellbore placement using Halliburton's CYPHER service.

The latest experimental development in this area is utilising complex well trajectories, with multiple horizontal legs radiating from the main horizontal to increase the surface area contact with the resource. This allows for a greater area to be targeted, thus allowing for increased production and a reduced need for fracture stimulation.

Offshore

Technology is paving the way for fracking to move offshore, enabling it to leave most of the social and environmental complications of onshore development behind, while extending its application to prolific shallow water basins in the Gulf of Mexico, North Sea and China's Bohai Bay.

The UK and South Africa are two countries where opposition to onshore shale development has been considerable, but where companies are proposing offshore fracking operations. It is cost, rather than safety or environmental concerns that is likely to be the biggest obstacle for offshore fracking, although use of existing infrastructure should help.

Although the practise has been around for years, high costs have meant its' extent has been limited in comparison to the onshore boom. In 2011, the offshore sector was estimated to account for 5% of the fracking market. Within this, 20% of offshore fracking took place in the Gulf of Mexico, with the other major areas of focus being Mexico, Brazil, the Arabian Gulf, West Africa and the North Sea - regions where conventional oil and gas projects have long been in operation.

Offshore fracking is being used on increasingly more complex formations, bringing new challenges with it, not least in keeping costs down. McMoRan Exploration's first ultra-deep Davy Jones well in the US Gulf of Mexico's shallow waters is currently undergoing fracking operations. The company ran into pressure problems, and is using fracking treatment to break through solidified drilling mud and get gas flowing. In South Africa, PetroSA is also planning to improve the productivity of its F-O field offshore Mossel Bay through the use of fracking.

As well as being used to boost output from mature fields, fracking is being employed in new offshore projects, including RWE Dea's Clipper South gas field on the UK Continental Shelf, which came on stream in 2012. Meanwhile, a small UK firm, Trapoil, announced earlier in 2013 that it was seeking a partner to hunt for oil in the Central North Sea, using fracking near existing infrastructure. Trapoil believes offshore fracking could double UK North Sea recoverable oil and gas reserves. Some estimates suggest the UK could have a staggering 1000 Tcf (28 trillion cubic metres) of offshore shale gas, although the British Geological survey has questioned this, pointing out that even if correct, the vast majority would not be recoverable - yet, at least.

CONCLUSION

There is little doubt that the use of the latest fracking technology can ensure safe development, given appropriate and tight regulation. So it should be possible for Europe, and elsewhere outside North America, to enjoy the benefits of shale gas, while effectively guarding against local environmental impact. The European economy and millions across the continent need the opportunities shale gas can bring. Europe's policy makers need to ensure that this happens, rather than simply focusing only on particular environmental risks or green dogma. While it is important to gain social acceptance through tough regulation, talking up the potential benefits also helps, and Europe should be doing both.

PKN Orlen said: "The EU should use the case of shale gas to rethink its approach to boosting innovation, not only in the energy sector but across the whole economy. It is time to consider why US innovation is more successful than European."

"The EU should use the case of shale gas to rethink its approach to boosting innovation"

— PKN Orlen

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