HOW TO EXPORT THE UNCONVENTIONAL REVOLUTION OUT OF NORTH AMERICA?

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ABSTRACT

In the space of six years, the United States have reduced their dependence on oil by a third and have become almost self-sufficient in terms of gas supply. This "shale oil and gas revolution", a sudden and unexpected earthquake in the energy world, enabled the US to become once again one of the most competitive countries in the world. Exporting this revolution could double the world gas reserves and boost those of oil by 20%. Outside North America, the main reservoirs are thought to be in China, Russia and Argentina.

In the medium term, this new state of affairs will have major geopolitical consequences, fundamentally altering oil, gas and coal imports. While US imports from the Persian Gulf rapidly dwindle, those of China and India will significantly increase and as the United States becomes a gas exporter, Russia will have to find alternative markets.

Although it is not ranked in the "top 10", Europe is thought to have vast resources. Yet for the achievement of a major European project, a number of geological (are European source rocks as high quality as their US counterparts?), economic (will Europe be able to develop its resources at an acceptable cost?) and societal barriers will have to be overcome. On a densely-populated, urban continent, hydraulic fracturing, water supply, microseisms and surface impact represent a battery of "threats" for the stakeholders. Changing this perception will require both pedagogy and transparency regarding the local communities.

THE SHALE OIL AND GAS REVOLUTION

The oil history of the United States is characterized by two major dates. In 1970, the US reached an oil production peak at 12 Mboe/day. In 2006 production fell to less than 7 Mboe/day while its crude oil imports topped at 14 Mboe/day. In 35 years, the oil dependency[1] of the US increased from less than 25% in 1970 to around 70% in 2006. During the same period, the gas dependency, unsignificant until the mid nineties, reached 15% in 2006. Let's take the analysis forward now to the following seven years, i.e. the period 2006 to 2014.

During this second period, the US oil production increased by 38% and at the same time, its imports decreased by 43%. Natural gas production also increased by 27% over the same period and gas imports fell dramatically by 60% (Figure 1). In six years, the United States reduced its oil dependency from 67% in 2006 to 47% in 2013 and became almost self-sufficient again regarding gas supplies (only 5% of remaining gas dependency). This change of paradigm is the so-called "*shale oil & gas revolution*". The 'explosion' was as sudden as it was unexpected. Between 2006 and mid 2014, shale gas production multiplied by 17, rising from less than 0.35 Mboe/day to 6 Mboe/day and that of shale oil was multiplied by ten, from 0.3 Mboe/day to 3 Mboe/day, making the United States the world's leading source of growth, well ahead of Saudi Arabia and Russia.

[1] The dependency is the ratio of imports on consumption

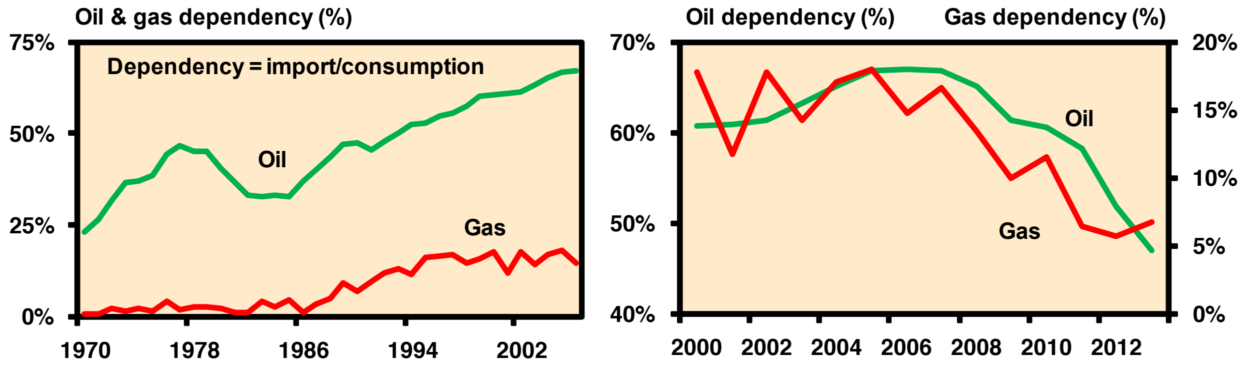


Figure 1 – Evolution of the US oil and gas dependency before and after 2006 (Source : BP 2014 Outlook).

The growing energy dependency of the US is not the only driver of the shale oil and gas revolution. The exponential growth of oil and gas prices between 2000 and 2008 was a second catalyst allowing to produce hydrocarbons at higher costs. In mid-2008, the barrel of oil hovered around the 150 US$ while the Henry Hub neared 10 US$/MBTU. But the shale oil and gas revolution cannot be explained by these exogenous factors alone. It is also based on four fundamental endogenous 'pillars' (Figure 2) typically characteristic of the United States:

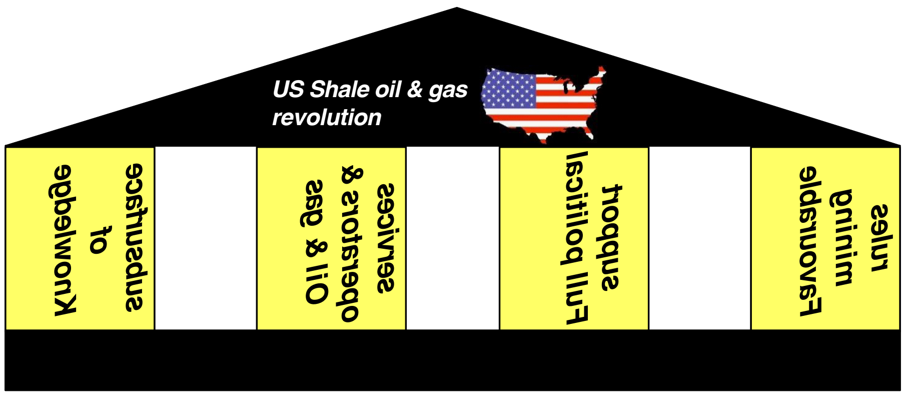


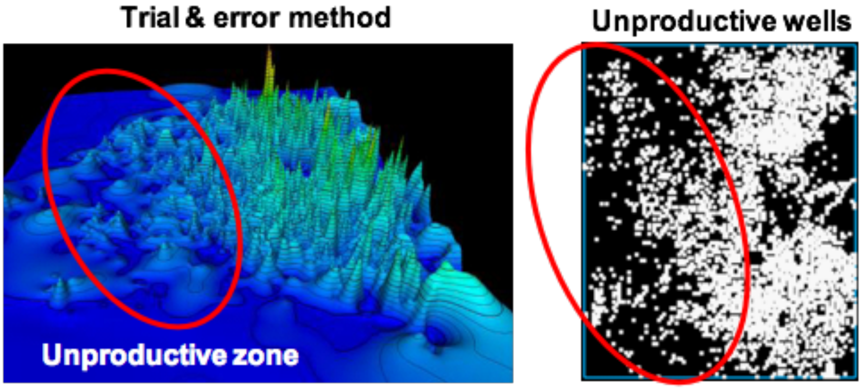
Figure 2 – Knowledge, political support, monopoly of equipment and law are the four main endogenous foundations of the "United States house"

- ✓ An extremely accurate knowledge of the subsurface recognized since the beginning of the XXth century and acquired by virtue of the several million wells drilled. By way of comparison, there are only a few thousand wells in Europe.
- ✓ A full political support. Whatever the administration, the American government promotes the opportunities through incentive-based legislation (employment, growth) and accepts the risks. In a certain sense, whereas politics in the "old continent" tends to restrict economics, in the New World it is politics that adapts to economics.
- ✓ A more than favorable mining legislation in that the subsurface belongs to the land owner, and not to the State, as is the case in most other countries. For land owners, exploiting the oil or gas is a sizeable financial advantage.
- ✓ An almost blanket monopoly on world oil and gas equipment. Of the 2,400 drilling rigs in operation worldwide, 80% are in the United States. They also have an abundant service offer in a very open and extremely competitive market. It has a decisive effect on the cost of wells, which represents 70% to 90% of investments.

Technologically speaking, there is nothing revolutionary about the development of shale oil and gas. It is based on the combination of two mature technologies – horizontal drilling, a technique used on an industrial scale since the beginning of the eighties and hydraulic fracturing, for which the first test dates back to….1947. The four endogenous pillars opened the way for the implementation of trial & error developments, highly suitable in terms of both operational (drilling time) and economic (well costs) performance (Figure 3). The trial and error method consists in drilling and then fracturing a very large number of low-cost wells, without analyzing the geological attributes in detail, and accepting that statistically, a significant percentage of them will under-perform.

Drilling	Days	11
Lateral length	Feet	4500
Well cost	M$	2,8

Source : Chesapeake



Source : SLB Terratek

Figure 3 –Example of remarkable operational performance and well costs in the Barnett. The "trial and error" model leads to a significant number of unproductive wells.

SHORT AND MEDIUM TERM CONSEQUENCES

The United States seized the opportunity presented by the shale oil and gas revolution to come out of the subprime crisis with its head held high. In September 2008, it had caused global turmoil and, less than four years later it had once again become one of the most competitive countries in the world.

The renewed competitive edge, in particular in the industrial sector, is due first and foremost to the collapse of gas prices on a market taken completely by surprise by this sudden influx. By mid-2012, the Henry Hub fell to below US$ 2/MBTU when the gas in Europe was at 10 US$/MBTU and the gas in Japan, following the Fukushima disaster reached 17 US$/MBTU (Figure 4).

Those who win out in the short term…are not the ones you might expect. It was not the Upstream oil sector (Exploration & Production), to a certain extent "victim of its own success" which reaped the benefits from the marked decrease in gas prices. However, activities related to the Midstream sector (gas transport and electricity generation), the Downstream sector (refining, petrochemicals and chemistry) as well as "energy-guzzling" manufacturing sectors (steel, cement and glass) significantly improved their profitability (Figure 5).

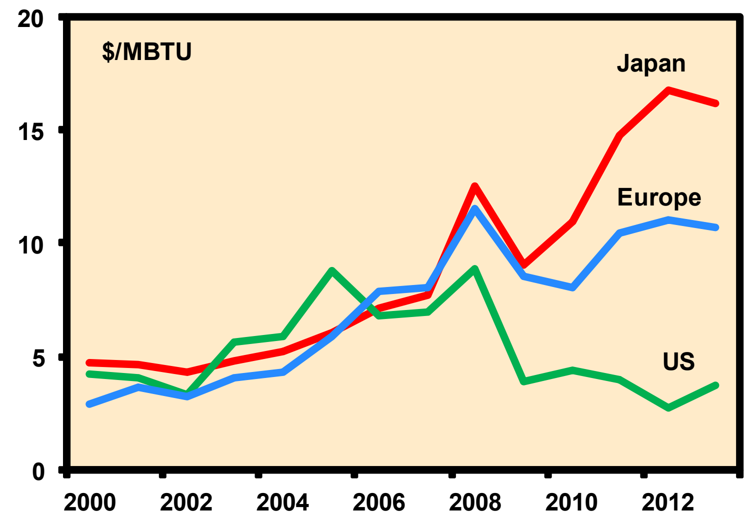


Figure 4 – Gas prices from 1999 in US, Europe and Japan (Source : BP outlook 2014)

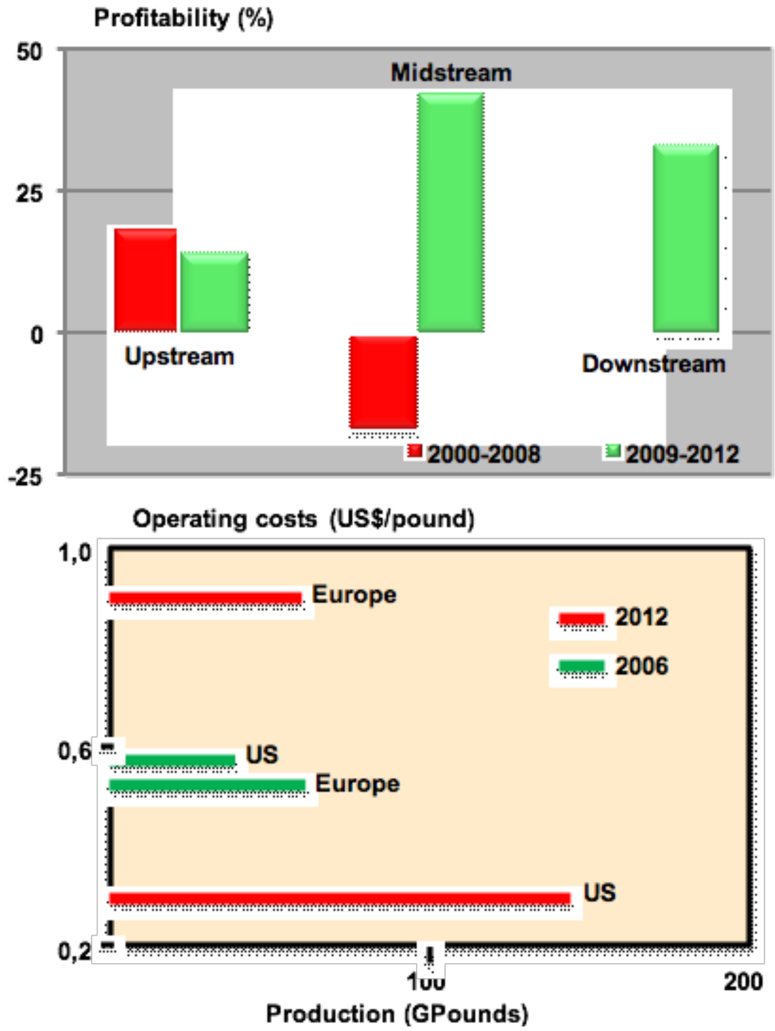


Figure 5 – Economic impact on the up/mid/down stream (source: McKinsey Corporate Performance Analysis Tool) Evolution of the competitiveness of the petrochemical industry between 2006 and 2012 in the US, and Europe (Source IFRI)

This spectacular revival triggered a domino effect in the industrial sector as a whole, with numerous jobs being created. According to IHS Global Insight (1), over the period 2006 to 2012 1.75 million jobs were created in the US. Above and beyond the activities directly linked to oil and gas production, the decrease in energy costs put a stop to outsourcing and generated employment in the above mentioned sectors. By contrast, the US boom had very detrimental effect in Europe particularly in Petrochemicals (Figure 5). Whereas in 2006 production costs in US/Europe were very similar (0.5 to 0.6 $/lpound), in 2012 US production costs had been halved, while over the same period, production costs in Europe had almost doubled. European production had become less attractive and stagnated, while across the Atlantic, the US were becoming an unprecedented “land of growth” (2) quadrupling their production capacity over the same six years. If this production cost difference persists, it is possible that the European refining and petrochemical industries, whose margins are currently negative, could relocate to the US, causing extensive job losses in Europe

The decrease in gas prices also compelled the United States to displace their electricity generating source from coal to gas. A significant number of coal-fired power stations were shut down impacting extremely positively the greenhouse gas emissions. Between 2008 and 2011 the US has decreased its coal consumption by 21% while at the same time its GHG emissions were reduced by 13% (Figure 6). By contrast, Europe remobilized some of its coal-fired power stations to partially compensate for its commitment to stopping nuclear developments (in particular in Germany) causing an unexpected increase in GHG emissions (+5,4% in Germany and +3,3% in UK).

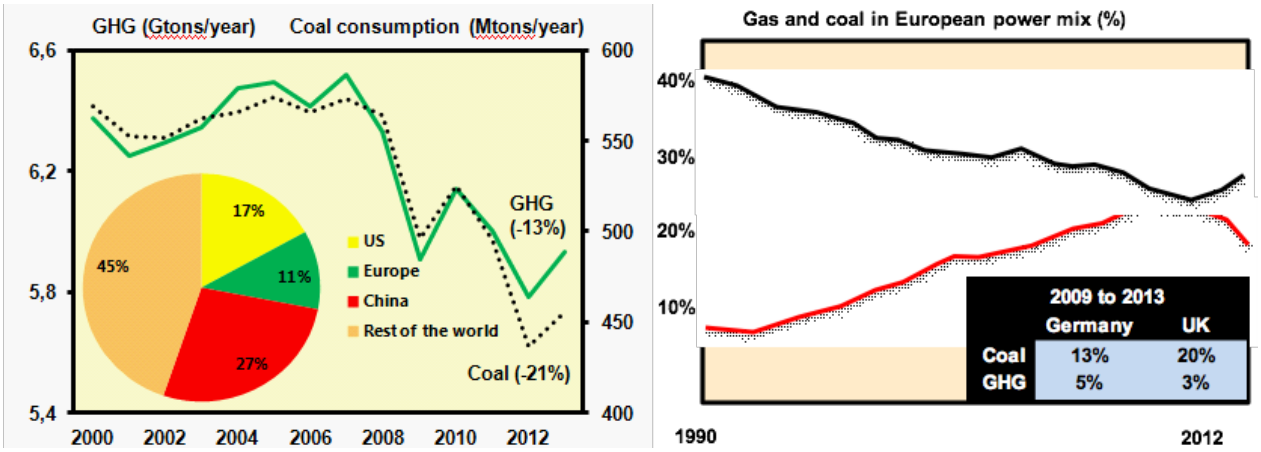


Figure 6 – Displacement coal to gas. Positive impact on GHG (source: BP outlook 2014))
In Europe a reversed situation is observed (source Pétrole & Gaz informations N° 1831)

SPECULATIVE BUBBLE OR LONG TERM SUSTAINABILITY

United States are the undisputed short term winner of the shale oil & gas revolution. Will they however be able to continue this unprecedented growth and reach energy self-sufficiency that some announce for 2020 – 2025 (3)?

According to the International Energy Agency (IEA), the shale gas potential should enable the US to become a prime LNG exporter from 2017. The production could reach 40 Mtons by 2025 and approach 100 Mtons ten years later, i.e. 25% of the 2035 forecasted LNG world market (Figure 7). Could this “LNG wave” cause a drop in gas prices and make the development of certain highly capital intensive projects in the Arctic(4) or in the deep offshore nonviable? From many perspectives, this new layout would weaken the Russian strategy[2]. As 75% of Russian gas exports are now destined for the European Union, the potential export of US shale gas at very competitive prices to markets that were traditionally the prerogative of Russia, represents a threat. So it is

[2] Russian reserves, estimated at 1,162 TCF represent approximately 18% of world gas reserves. BP 2013 outlook

essentially to China[3] and to a lesser extent, India that Russia would have to look and gradually develop a Sino-Russian gas axis.

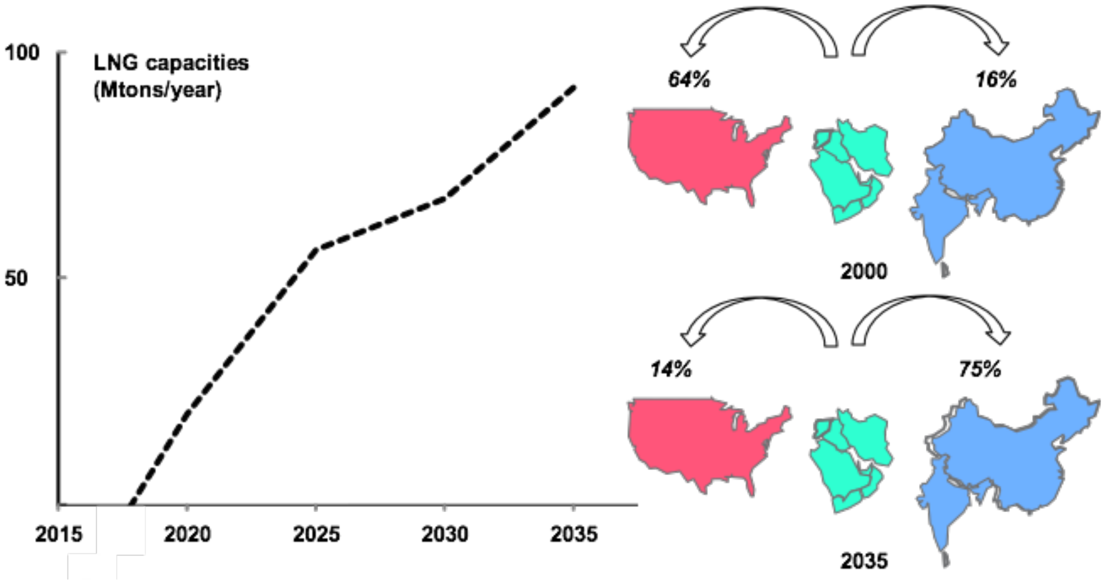


Figure 7 – Potential LNG export ramp up in the US (Source: IHS CERA)
Evolution of oil flow between the Middle East, China/India and the US
(Sources: IEA outlook 2012)

As for oil production, IEA predict a "second flat oil peak"[4] between 2020 and 2025. However, contrary to certain rumors (5), oil self-sufficiency does not seem realistic. Coupled with a decrease in consumption, in the best case scenario, the production of shale oil could reduce the US oil dependency to 25%, imports falling from 9 Mboe/day in 2013 to just 5.4 Mboe/day in 2020 and to 4 Mboe/day in 2025. Shale oil in the United States should however, in the medium term, significantly alter hydrocarbon flows which in turn will affect the geopolitical equilibria worldwide (5). Between 2010 and 2030, while oil imports in the United States would be halved, those in China and India will triple. As these mass imports come essentially from the Middle East, China and India will become the main clients of the Gulf monarchies (Figure 7). The figures are startling: in 2035, US oil imports from the Gulf would represent just 15% (compared with 64% in 2000) whereas those of China and India, which were just 14% in the year 2000, will top 75%.

However, the scale, suddenness and unprecedented general euphoria induced by the shale oil & gas revolution raised a critical question: is this revolution sustainable or are we facing an economic bubble (6) as feared by certain analysis? In addition to a contextual crash in gas prices certain experts are wary of the promises being made. They consider that future production levels and the ultimate reserves are wildly overestimated (7, 8). These fears mainly rely on the rapid decline of well productions, a phenomenon inherent to the extremely low permeability of the source rock and to the recovery technique used (9). According to critics, the "trial and error" method which entails drilling and fracturing new wells one after the other to offset the extremely rapid decline of existing wells is not viable in the medium-term and will generate an economic bubble. The withdrawal of investors would stop developments and trigger a rapid marked decline in production.

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[3] The gas demand has doubled since 2007, rising from 7 to 14 bcf/day. Gas however, represents just 4.5% of the Chinese domestic gas demand.

[4] i.e. almost equivalent to that in 1970

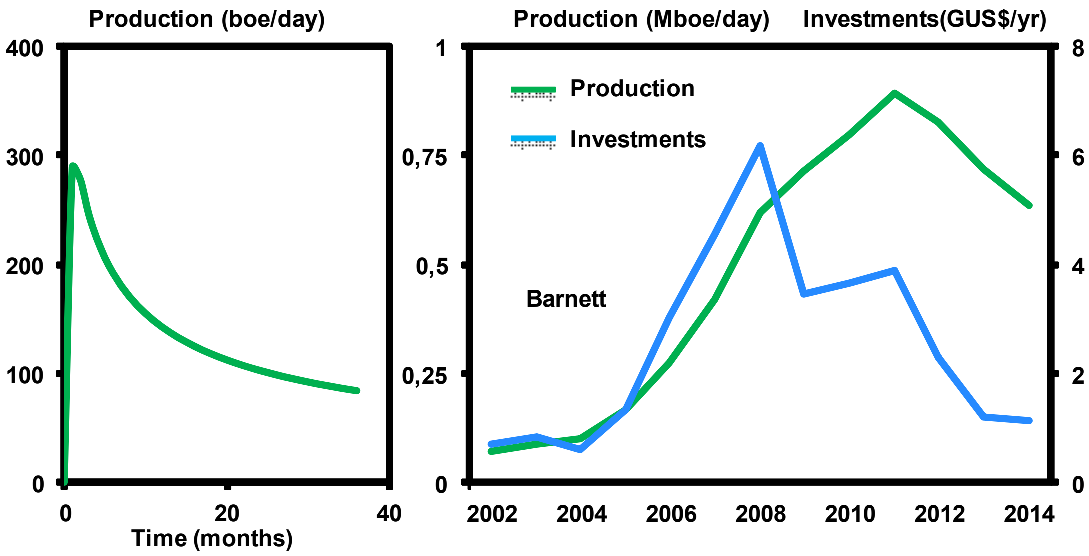


Figure 8 – The decline of the Barnett[5] field (right) does not reflect the individual decline of a well (left). A latency of several years can be seen between the slowing down of investments which began in2009 and the decline in production which started in 2012 (Source: Wood McKenzie)

In reality, the well-by-well analysis is deceptive in view of the amazing number of wells drilled, fractured and brought on stream over the last few years. At the end of 2013, North America (United States & Canada) had a portfolio of some 100,000 shale oil & gas wells on fields at different stages of maturity. In spite of the rapid individual well decline, the huge well stock acts as a “buffer” which helps limit the overall decline for several years without having to continue drilling and fracking frenetically. For instance, the significant slow-down in investments which began in 2009 on the Barnett field did not lead to plummeting production figures (Figure 8).

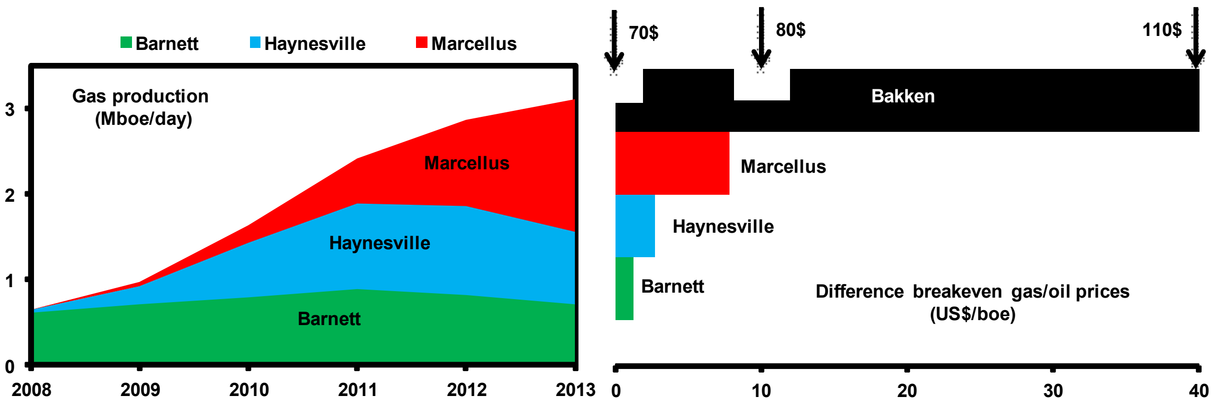


Figure 9 – The production decline on the Barnett and Haynesville developments has been offset by the spectacular progress of the Marcellus. In the Bakken (shale oil) the break-even point is now close to current oil prices (source: Wood Mc Kenzie)

The slow decline in production on the Barnett and Haynesville developments, where the break-even points[6] are too close to current gas prices (**Figure 9**), were more than offset by the spectacular progress of production on the much more profitable Marcellus play.

[5] Barnett is in North Texas, Haynesville Texas and Louisiona, Marcellus Pensylvania and Ohio and Bakken North Dakota

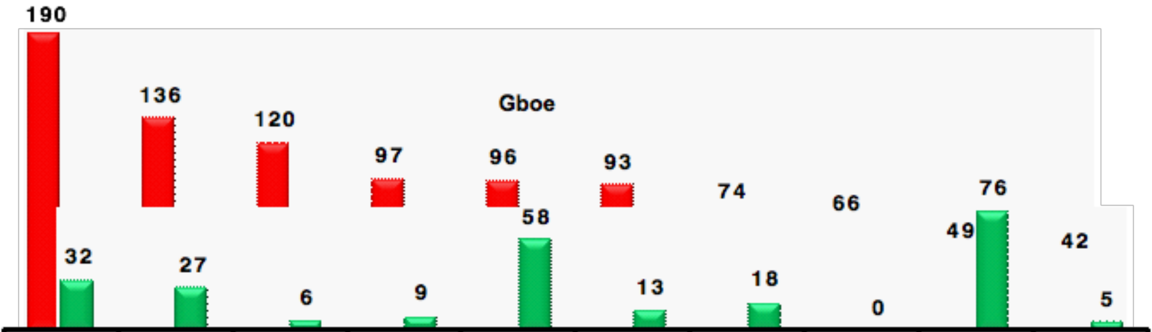
[6] Gas price which cancels out the Net Present Value 10%

Similarly but with a 2,5 years delay, the oil market which has seen unexpected barrels arriving on the market recently experienced a very sharp decrease in prices dropping from 110 US$/bbl in June 2014 to 60 US$/bbl in December 2014. Small independents but also major companies, victims of their operational success, will therefore suffer from a “double punishment” of low oil & gas prices. The breakeven oil price in the Bakken or the Eagle Ford being in the range of 65 US$ (Figure 9), the activity is expected to slow down over the next months. However given the number of drilling rigs and fracturing fleets available in the US, shale oil & gas production is amortized enough to exclude the possibility of an economic bubble. By contrast to large capital intensive arctic or deep water oil & gas projects (10), shale oil and gas can more easily slow cyclically and adapt to a “stop and go strategy”.

Nonetheless, shale oil & gas is clearly not an easy prey, and producing it sustainably and economically requires an in-depth review, even in the United States, of the applicability of the “trial and error” method, the limitations of which are now only too apparent. The new prices panorama encourages operators to adopt more scientific approaches, in particular those that help pinpoint sweet spots (11) more accurately, in order to increase both the reserves by wells, while limiting their number. Thanks to such technologies for example, the break-even price for gas was reduced by 35% for the Marcellus between July 2012 and early 2014.

FROM THE 4 PILLARS OF SUCCESS TO THE 4 LEVERAGES OF EXPORTATION

The North American subsurface is far from being unique in terms of the quality of its source rocks. All the regions of the world that produce conventional oil and gas have source rocks, and therefore shale oil and gas resources. From Australia, through Europe and China to Argentina, there are myriad reservoirs, some of which are very promising and of higher quality than those in the United States.



	China	Argentina	Algeria	Canada	US	Mexico	Australia	South Africa	Russia	Brazil
Gas	190	136	120	97	96	93	74	66	49	42
Oil	32	27	6	9	58	13	18	0	76	5

Figure 10 – The top 10 for shale oil and gas resources
Recoverable resources by country (EIA report 2013)

In its latest report published in 2013, the EIA (12) estimates that the worldwide technically recoverable resources are somewhere in the region of 1,200 Gboe for shale gas and 347 Gboe for shale oil. Outside North America, the largest gas reservoirs are thought to be in China, Argentina, Algeria and, to a lesser extent, Australia and South Africa, whereas for oil it is Russia that holds the largest resources, followed by China and Argentina (Figure 10). Even though it is not one of the ‘top 10’, Europe is thought to have significant gas resources essentially in Poland and France, and to a lesser extent Romania, Great Britain, Denmark and the Netherlands. These unconventional hydrocarbons could theoretically double conventional gas reserves, estimated at 1,100 Gboe and boost conventional oil reserves, estimated at 1,650 Gbbls (13) by 20%.

These notional evaluations must nonetheless be considered with the greatest caution since, apart from North America, they are based on simplistic volumetric calculations and do not factor in the economic, political and cultural contexts. Although a thorough knowledge of the geology of a reservoir is the first milestone in the process of extracting reserves, it cannot by itself successfully export the American revolution. Once the geological uncertainties have been lifted, the maturity of a region will depend on a number of different parameters that will either help or hinder future developments (13):

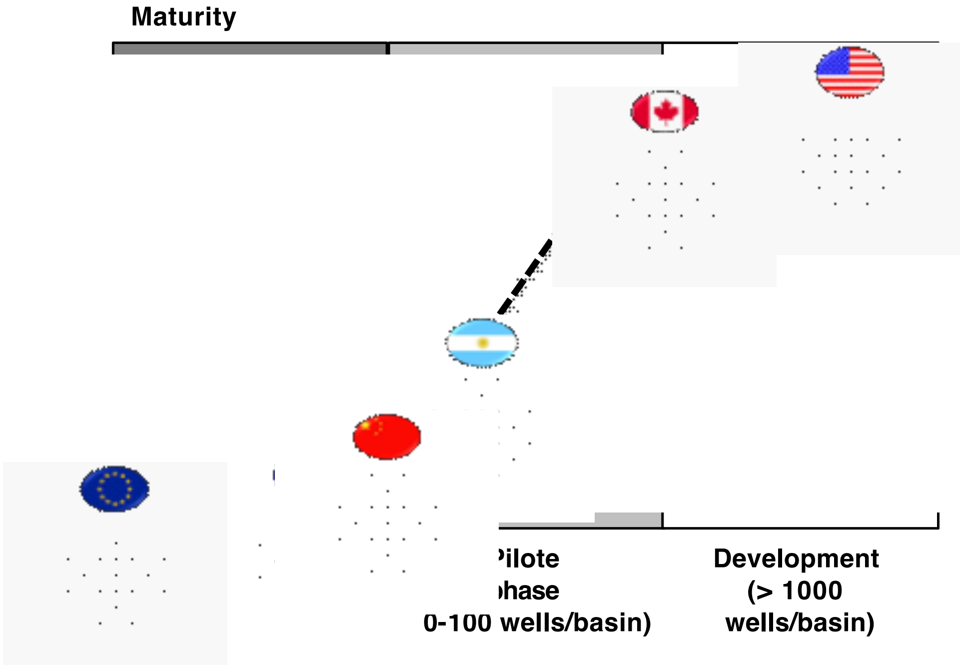


Figure 11 – Learning and development curve for different regions (Source : IHS CERA)

A rough division of the 'learning curve' above into three periods (an initial period to estimate the resources in place, an appraisal period with business pilots being run and an advanced development period - Figure 11) plainly demonstrates that outside the United States and Canada, unconventional resources are only in the early stages of development (14) .

Exporting the unconventional revolution out of North America will not be an easy task. In particular, the much higher well costs make trial and error not really a viable option particularly during a low prices period. Consequently, four leverages have been clearly identified to export the development of shale oil and gas out of North America. They are represented by the four faces of a tetrahedron (Figure 12)

The first leverage deals with optimising reserves per well by locating possible areas which associate a high quality source rock (thick and rich in hydrocarbons) and an aptitude (presence of natural fractures, brittle rock) to generate complex and extended fissuring by hydraulic fracturing. However, the so-called "sweet spot approach" is also highly criticized. According to Haskett (15) "*searching too early (i.e. during the exploration phase) sweet spot in a high variability reservoir appears inefficient since based on imperfect interpretation. It destroys project value, potentially misrepresent the project potential and delay efficient development. The value of an acreage is the aggregated value of the entire developed area. Sweet spotting only provides a competitive advantage later in the development phase and not during exploration phase*". So "trial and error versus sweep spotting" the debate remains open.

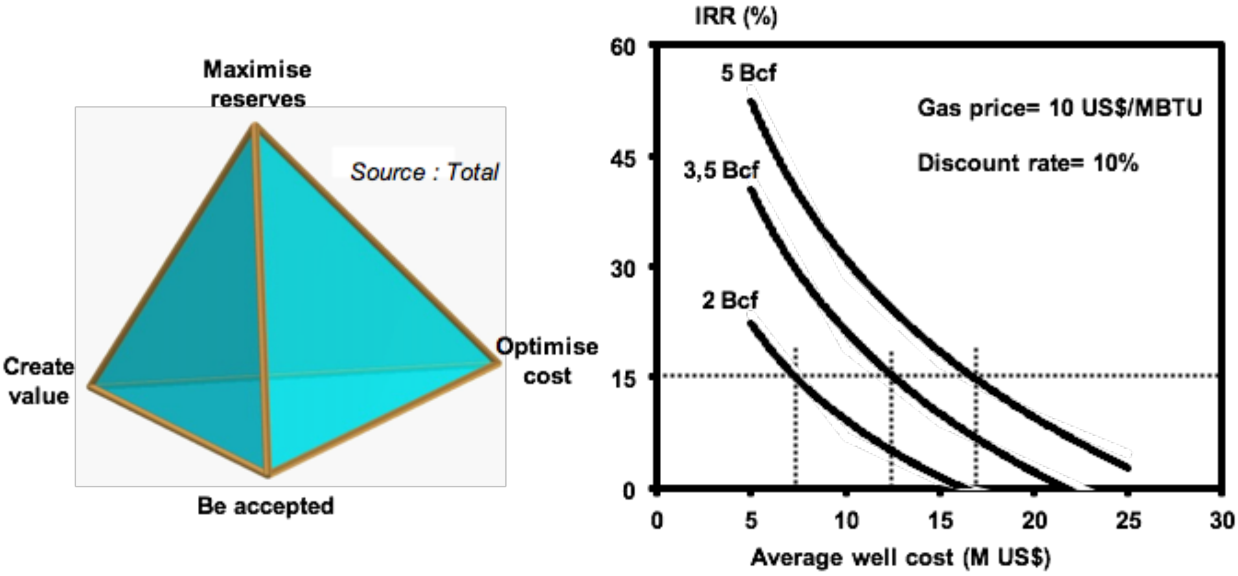


Figure 12 – The four leverages of exportation
Reserves per well and well cost are the first two main leverages.
To obtain an Internal Rate Return) of at least 15%, an iso-Barnett well must be drilled for US $ 13 M before taxes and for a gas price of US$ 10/MBTU
Source: Total UFD^{sim}.

Well costs appear as the second leverage. They represent between 70% and 90% of overall investments and determine the economic legitimacy of a shale oil and gas development project. The cost parameters can be divided into two main categories: on the one hand, time-related variable cost (daily rental of the drilling rig or associated services) and fixed costs (drilling, fracturing and surface production consumables). According to their respective impact, drilling and fracturing fixed costs which affect each well have a major influence on the economic viability of the project whereas time costs (i.e. drilling time) have a limited impact. This reflects the crucial importance of standardizing well and surface equipment purchased in large quantities and negotiated in the context of extended contracts in a highly-competitive market. Any kind of monopoly (public or private) in the services sector (drilling or fracturing contractors) or equipment and consumables suppliers (tubing, mud, cement, sand, chemicals) will inevitably lead to spiraling costs and to the economic non-viability of the project.

Considering the European market (a discounting rate of 10% and a gas price of $US 10/MBTU) obtaining an IRR of 15% requires drilling wells at somewhere between 7 (for 2 Bcf/well of ultimate reserves) and 16.5 million dollars (for 5 Bcf/well of ultimate reserves). An iso-Barnett well[7] (3.5 Bcf of associated reserves) should be drilled for approximately 13 million dollars[8]. Since oil services are currently not competitive enough in Europe (few drilling rigs, almost no fracturing fleets, monopoly of a few major International Service Companies), the minimum integrated cost of a well can be estimated at around 20 million dollars. Unless very high potential source rocks are found, the market as it stands would not be conducive to the cost-effective production of European shale gas. Making such developments profitable will require a significant reduction in the cost of wells, in particular by encouraging the emergence of a local competitive oil services market, especially in the drilling and fracking sectors. Yet this requires first and foremost determined political support.

The third leverage covers all the societal and cultural issues. In North America, the population has been used to living near drilling rigs, fracturing equipment and production facilities for decades unlike the population of the “Old Continent”, which has barely any oil culture. In a densely populated Europe, hydraulic fracturing, water supply, microseisms and surface impact are seen as

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7 Similar to an average well from the Barnett play

8 All these figures are given before tax

a battery of threats by certain stakeholders. Changing this perception will take more than scientific reasoning. Winning over public opinion requires pedagogy, transparency, appropriate communication campaigns and commitment regarding local communities (16, 17) with an in-depth review of certain regulations.

The fourth leverage is "*value creation for everybody*" or win/win game for all shareholders and stakeholders. Except in the US, mining rules are always favourable to the national government which does not encourage local authorities and local communities to be proactive. An improvement in the way in which income is distributed, in particular to local communities, would be a real step in the right direction.

CONCLUSION : AN EUROPEAN NOTIONAL PROJECT

In 2013, the gas dependency of Europe was equal to 67% (41,4 Bcf/day of imports for 13,6 Bcf/day of production - 18). Its cost was nearly 100 GEuros that is 0,7% of its global GDP. Without any shale gas development and given the decline of the conventional gas fields in the North Sea, the dependency will reach 95% by 2035.

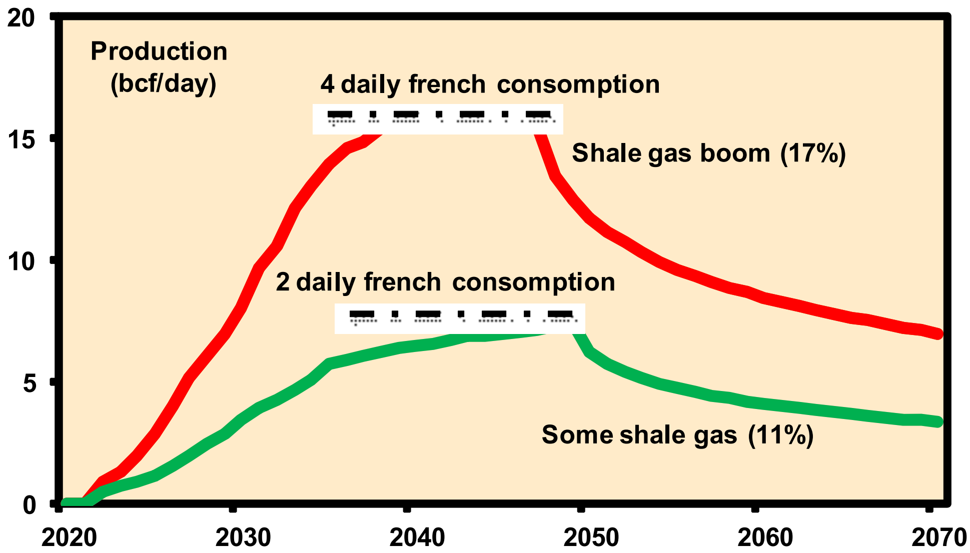

Figure 13 – Two shale gas development projects (source : Poyri/IOGP)

According to the EIA (19), the European gas resources would be in the range of 80 Gboe (i.e. 470 Tcf) of shale gas. After applying to these resources a number of technical (non-recoverable resources), environmental & societal (national parks, densely populated urban regions) and economic (excessive development costs) filters, two scenarios spanning the period between 2020 and 2050 (Figure 13) have been studied (20). The first, "some shale gas", ambitiously forecasts a peak at 7 Bcf/day[9] (7 /day) to produce 8.6 Gboe (11% of EIA gas resources) by 2050. The second, "shale gas boom" predicts a pseudo plateau of 16 Bcf/day (2.7 Mboe/day) with resources of 20 Gboe by 2050 (17% of EIA gas resources). In the absence of any real production data, an average equivalent Barnett well (550 kboe of ultimate resources) has been considered.

To create the production profiles shown in Figure 13, approximately 23,000 wells would need to be drilled for the some shale gas scenario and over 50,000 in the shale gas boom scenario, with peaks of 1,000 and 3,000 wells respectively around 2035 which, assuming drilling PADs of 10 wells, would require the mobilization of 100 to 300 drilling rigs. In terms of the footprint over the 28 countries of Europe, the total surface area used would be somewhere between 250 km^2 and 500 km^2, equivalent to that of Lake Geneva. To satisfy the needs of hydraulic fracturing, the total water usage would be somewhere between 500 million m^3 and 1 billon m^3 over thirty years. So in the

[9] The daily consumption of France is 4 bcf/day (I;e. 0,7 Mboe/day)

"shale gas boom" scenario, the peak water usage would be around 60 million m^3 in 2035, a value to be compared with annual water consumption in France which, for 2012 alone was 33 billion m^3.

The most significant macroeconomic impacts resulting from these two scenarios would be (21) :

- ✓ By 2035, Europe's energy dependency on its main gas suppliers (Russia, Norway, Algeria) would be reduced to 78% in the case of the "some shale gas" scenario and to 62% in the case of the "shale gas boom" scenario (compared with 95% in the absence of any development).
- ✓ By 2035, the development of shale gas would reduce the price of gas by 20% in the case of the "shale gas boom scenario" and by 10% in the case of the "some shale gas scenario".
- ✓ The development of shale gas would cause a cumulative increase in the European GDP of between 1,600 G€ and 3,400G€ over the period 2020 – 2050, i.e. an average contribution to annual growth of between 0.3 and 0.6%.
- ✓ By 2050, shale gas development would generate between 0.5 and 1.1 million jobs (direct, indirect and induced).

Oil flow from the Middle East to India and China; Chinese companies replacing the Americans in the Middle East; gas and coal flows from the US to Europe; the United States meeting emissions targets that it has not signed and Europe falling short of them in spite of itself; Russia sanctioned (22) and at a loss for external outlets for its gas in a flooded LNG market: "our energy future is not set in stone" (23).

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