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How to export the Unconventional Revolution Out of North America ?

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Background

According to the International Energy Agency [1], the world is entering a "*golden age of gas*". Following a large displacement of the electric generation from coal to gas, the consumption of natural gas should account in 2035 for nearly 25% of global primary energy demand. Natural gas appears at the same time as an abundant but also a greener resource as emitting two times less GHG than coal. This golden age will not only rely on conventional resources. Shale gas will play a key role in the future energy mix.

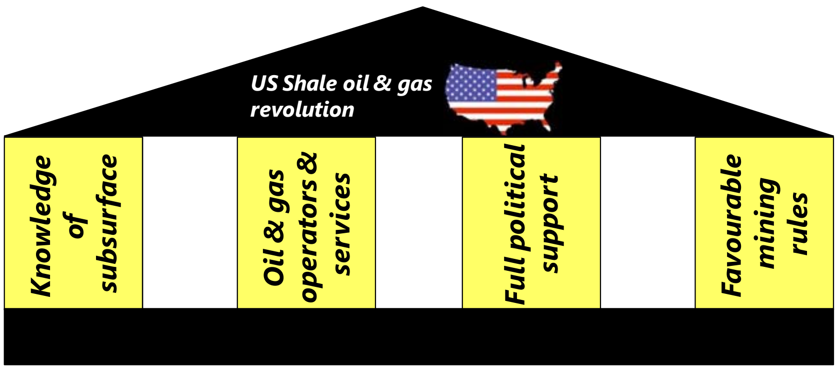

Figure 1 – The four pillars of the shale oil & gas US revolution

US have demonstrated over the last five years through their "*shale gas revolution*" that these resources are large, attractive and can be quickly developed. They accounted in 2014 for 40% of the US gas production (against only 2% before 2005). Technologically speaking, there is nothing revolutionary. Developments of shale gas are 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. However, the US have benefited from four major "*pillars*" [2]: knowledge of the subsurface, political support, existence of many operators and service companies in an open and competitive market and favourable mining rules (**Figure 1**).

These four pillars have opened the way for the implementation of factory developments using the "trial & error" method. It consists in drilling and fracturing a very large number of wells, without analyzing the geological attributes in detail, and accepting that statistically, a significant percentage of them will under-perform (**Figure 2**).

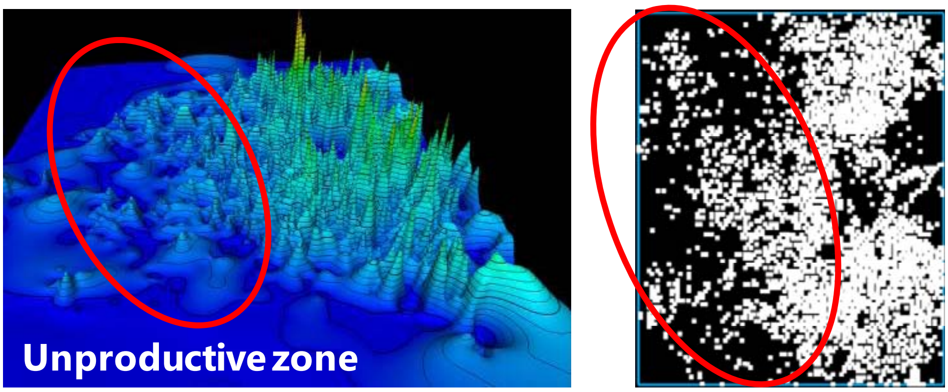

Figure 2 – Left : play highlighting high production and unproductive zones. Right : well map. 30% of the wells have been drilled in the unproductive zone
[2bis]

Such a strategy is only compatible with unbeatable operational performance (drilling time) and operating costs (drilling and fracturing costs). For instance, in the Barnett shale, a well at a vertical depth of 2500 m, 1500 m of horizontal extension and including 15 fracturing stages will be achieved for less than 3 MUS$[1].

Aim

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. In its latest report published in 2013, the EIA [3] 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.

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 by 20% [4].

[1] Source Chesapeake

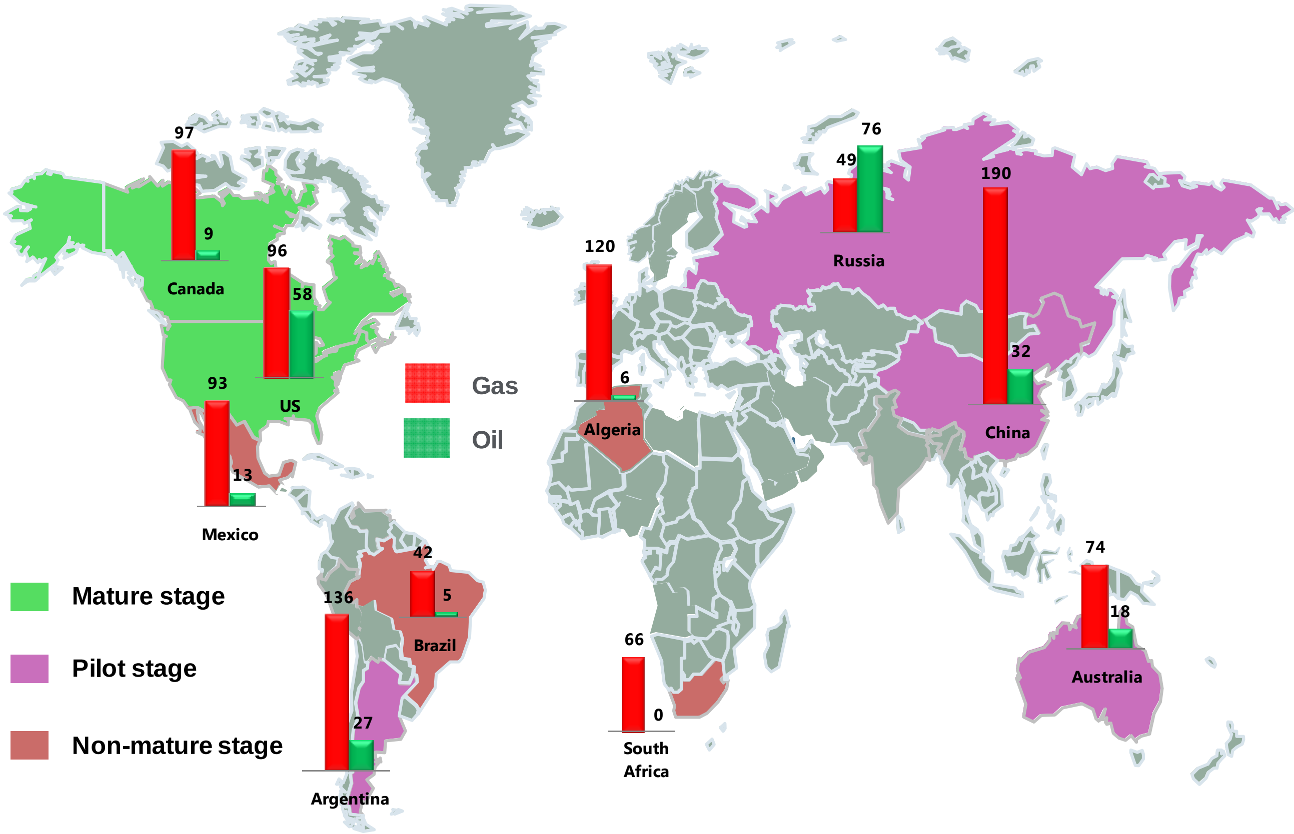

Figure 3 – The top ten of unconventional. Unit is Gboe
(Source : EIA 2014)

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 method not a viable option. The aim of the paper is to highlight that exporting this revolution outside North America and in particular in Europe relies on four leverages described below.

Methods

The four leverages required to export the US revolution are (**Figure 4**):

- ✓ maximize reserves per well and avoid a too high percentage of unproductive wells,
- ✓ optimise well costs insofar as DRILLEX represent 70% et 90% of the total CAPEX
- ✓ overcome acceptability barriers to transform fear in a global acceptance
- ✓ create value for all stakeholders

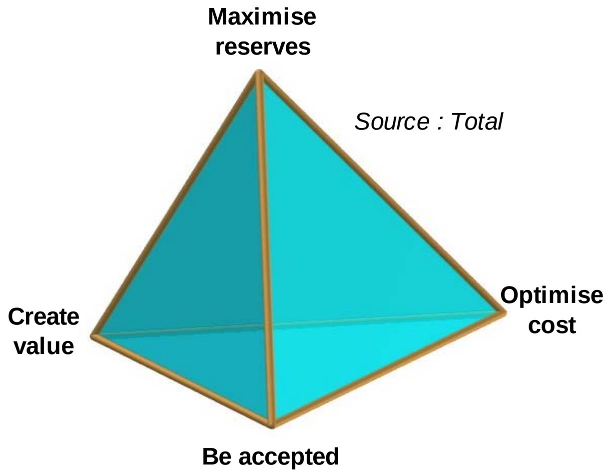

Figure 4 – The four leverages to export the US revolution out of North America

Results

Increasing reserves per well requires locating areas of high quality source rock (thick and rich in hydrocarbons – play quality) with an aptitude (presence of natural fractures, brittle rock) to generate complex and extended fissuring zones by hydraulic fracturing (SRV[2] quality). For instance, the Bratford area in the North West Marcellus exceed 2,5 Bcfe/1000 ft of lateral whereas other sub play rarely reach 1,5 Bcfe/1000 feet lateral [5].
However, the so-called "sweet spot[3] approach" is also subject to criticism [6]. In fact, searching too early the sweet spots during the exploratory phase can be highly risky insofar as one focuses development on a targeted area forgetting a fair assessment of the entire play. It can lead to either a false negative ("we do not find the sweet spot and withdraws") or a false positive assessment ("we find and develop the sweet spot but we miss peripheral economic resources"). Somewhere, searching too early a sweet spot extrapolates the conventional philosophy to unconventional. A conventional reservoir is just a super sweet spot with no resources around! So "full development area" versus "searching sweep" remains an open debate.

Another way to increase the EUR/well is to optimize well completion regardless of whether the well has been drilled into or out of a sweet spot. Optimize the well completion means developing a complex and efficient SRV in the fracturing zone as well as a clean connection between the well and the SRV to avoid any "traffic jam". Improving well and completion design includes optimizing horizontal length, number and size of fracturing stages, use of slick or X^{linked} fluid and proppant concentration. In the Haynesville play [7] improvements in drilling and completion (**Figure 5**) have allowed to dramatically increase the EUR/well by

[2] Stimulated Rock Volume
[3] Zones of both good play and SRV qualities

50%. To reach these performance laterals have been increased by 15%, water volumes and proppant concentration by 30%, number of fracture stages have been doubled and pumping rates have approached 80 bbl/min.

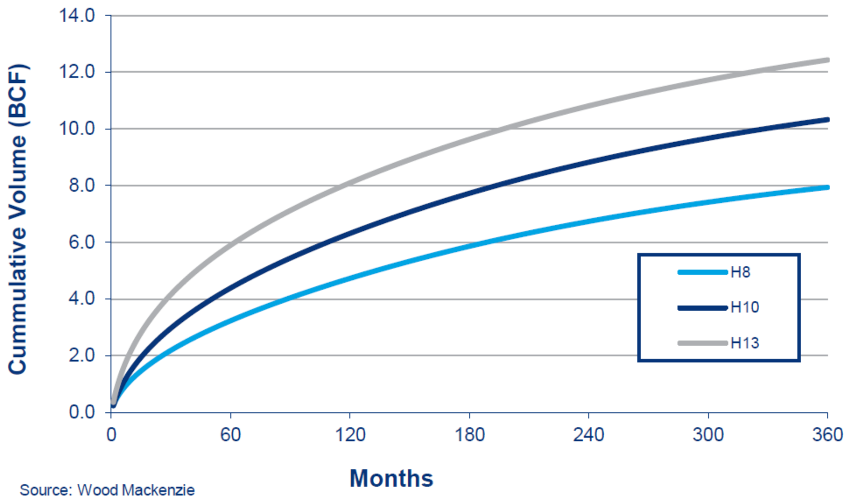

Figure 5 – Evolution of EUR/well in the Haynesville following the improvement of the completion technique
(source : Wood Mc Kenzie)

DRILLEX which represent between 70% to 90% of overall CAPEX determine the economic legitimacy of a shale oil and gas development project. ***Decreasing well costs*** while complying with all safety and environmental constraints is therefore the second leverage. The cost parameters can be divided into two main categories: on the one hand, time-related cost (daily rate of the drilling rig and associated services) and fixed costs (drilling, fracturing and surface production consumables, fracturing services). According to their respective impact, drilling and fracturing fixed costs will have a major influence on the economic viability of the project whereas time costs (i.e. drilling time) will have a more limited impact. This reflects the crucial importance of standardizing well and surface equipment purchased in wholesale and negotiated in the context of extended contracts in a highly-competitive market. Any kind of monopoly (public or private) in the sector of services (drilling or fracturing contractors) or equipment and consumables suppliers (tubing, mud, cement, sand, chemicals) will inevitably lead to spiralling costs and to the economic non-viability of the project. For instance, in the European context with a gas price at 10 US$/MBTU, to get a pre-tax IRR of 15% (**Figure 6**) an iso-barnett well (EUR of 3,5 Bcfe/ well) will require an integrated well cost (drilled/fractured/connected) in the range of 12,5 M$. By increasing the reserves at 5 Bcfe/well the same pre-tax IRR could accommodate with an integrated well cost of 16 MUS$.

The third leverage "***be accepted***" covers all health, safety, environmental and social 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 is seen as a threat by certain stakeholders.

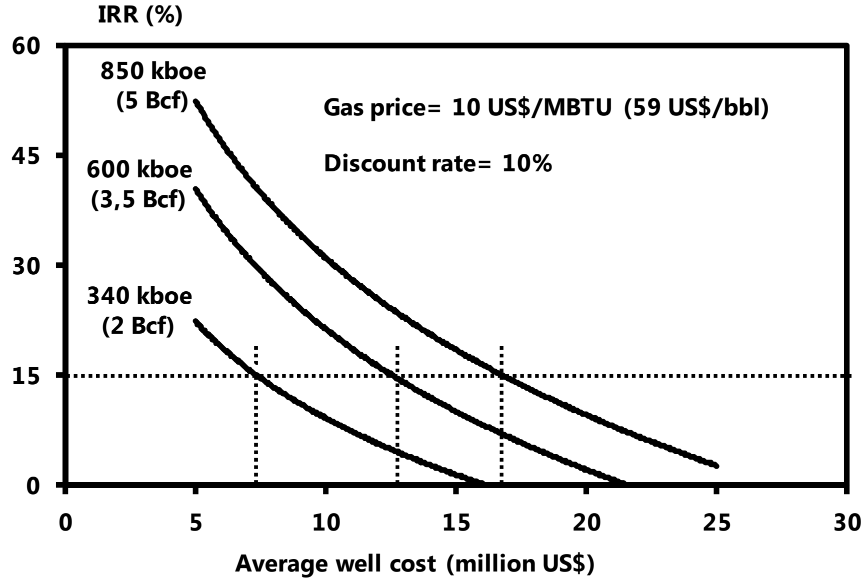

Figure 6 – Pre-tax Internal Rate Return versus well cost.
Gas price is 10 US$/MBTU and discount rate 10%
(source Total)

Even though the threat related to shale gas has essentially been built up around "suggested" impressions (i.e. the Gasland film with the "faucet on fire") and not hard facts, the risks associated with development and production activities must not be denied. Restoring a capital of trust requires the issues to be explained in total transparency and to educate people to make the difference between hard facts and sensational rumors.

To achieve this, the issues likely to cause environmental or social incidents must be classified into three categories (**Figure 7**): nuisances, which are certain events (100% probability of occurrence) but with a low criticality, risks in the strict sense and the myths associated with a high criticality but with an extremely low probability of occurrence.
Nuisances, risks and myths are all treated differently. The criticality of nuisances is mitigated; risks are reduced by acting both on their probability of occurrence and their criticality. As for myths, which in public opinion are often the main threat, they must be dispelled using demonstrative measures, an open, instructive communication strategy and a language that can be understood by all.

Once all the issues have been identified and classified, a baseline must be established within the project perimeter to distinguish the potential risks from the issues that may arise from existing activities (domestic, industrial, agricultural). In most producing countries, this environmental baseline study is a legal requirement. It is usually carried out by a third party and covers many aspects such as the cartography of the flora and fauna, seismic activity, natural radioactivity, air and water quality, ground conditions and legacy pollution inherited from former industrial projects.

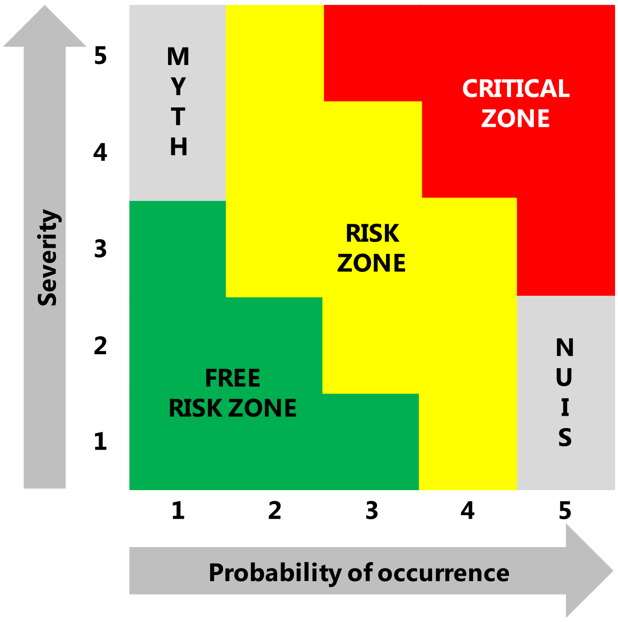

Figure 7 – Conventional criticality/probability of occurrence diagram
Nuisances are placed in the bottom right-hand corner and myths in the top left-hand corner. The central part of the diagram covers risks in the strict sense.

The social baseline study, carried out at the same time, is designed to map out the socio-economic context: demography, health, employment, housing, transportation. It also covers the map of stakeholders, in particular the local communities that are directly affected by the nuisances. Anticipating their perceptions is essential, insofar as a crucial issue for one group of stakeholders may be secondary for another. The baseline study is followed by an impact study, also a legal requirement and designed to quantify the incidence of project activities relative to the baseline study. All the issues covered in the impact study will be continuously assessed throughout the production period using appropriate monitoring systems.

The main health, safety and environmental issues presented in **Figure 8** have been breakdown into nuisances, risks and myths.

The main nuisances that must be mitigated are:

- ✓ The surface impact of operational activities (surface footprint, truck traffic, road damage, eyesores, noise and olfactory pollution related to operations, light, dust).

- ✓ Greenhouse gas emissions generated by exhaust fumes or discharge when a well is cleaned up.
- ✓ Water requirements and possible conflicts regarding usage.
- ✓ Waste, in particular the recovered fluid which has to be treated to be preferably reused

The main risks to be reduced are:

- ✓ Transportation accidents (related to truck traffic, sand or oil transport by train [8])
- ✓ Any surface pollution caused by an accidental spill (on site or as a result of an accident involving a truck carrying non-ecological products - e.g. chemicals).
- ✓ Well integrity issues [9].

The main myths to be dispelled are:

- ✓ The pollution of water-bearing layers as a result of the uncontrolled migration of a hydraulic fracture
- ✓ Earthquakes caused by hydraulic fracturing.
- ✓ Fugitive methane emissions caused by uncontrolled leaks from the well or from the pipelines carrying the gas to the processing plant.

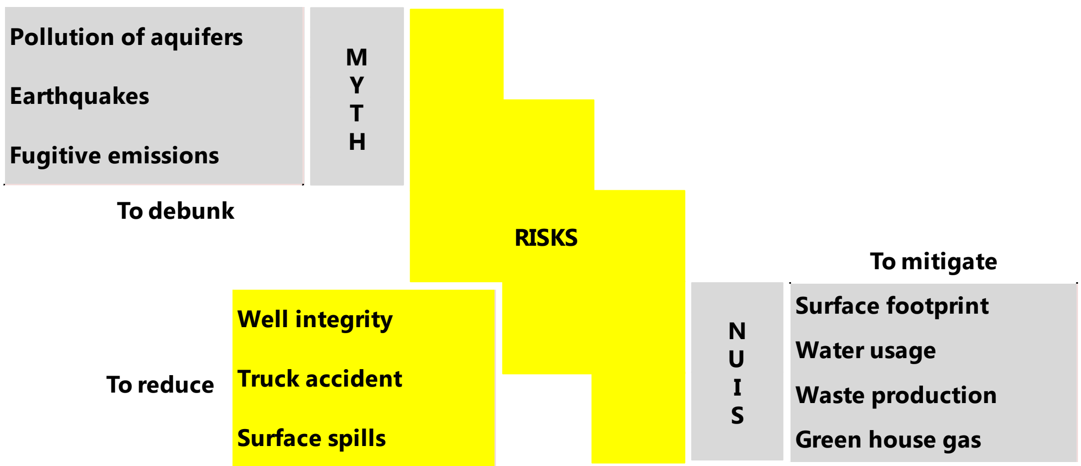

Figure 8 – Nuisances, risks and myths associated with the development of shale oil and gas

If the acceptability has become one of the keys, the goal of any Oil & Gas project is to ***create value for the all stakeholders*** (State, NOC, IOC, local authorities and communities).

For producing countries, the value lies primarily in the development of its long-term resources whereas for an IOC, the medium-term profitability can be the primary goal. Developing a shale gas play can therefore lead to competing strategies.

The first one is to look for high productivity and EUR areas (i.e. sweet spots) from the exploration phase. This "high risk, high reward" strategy is similar to conventional. It is highly risky (as conventional reservoirs, the sweet spots are difficult to locate) but very profitable for the IOC insofar as in case of success, it is associated with a high IRR. By contrast, for the State, such a strategy leaves most of resources (around the sweet spots) undeveloped.

The second strategy aims at developing the entire block on which the State has granted a license to the IOC leaving the sweet spots "appear naturally" during the development phase. This strategy, not so far from the American trial and error method, requires huge investments (thousands of wells to be drilled and fractured) and is associated with a lower IRR insofar as average reserves per well remain globally low.

Unlike conventional (a reservoir is nothing all than a "super sweet spot" with no resources at the periphery), the very heterogeneous geology and the huge extension of unconventional resources therefore encouraged to create contracts with variable terms. Encourage on one hand the IOC to de-risk the entire block (and not only sweet areas) with an attractive tax regime then, adjust this tax regime when the sweet areas have been identified. For instance, in a regulated domestic gas market, the state will buy the "gas block" at a higher price than the "sweet spot gas".

However, the oil & gas rent should not only benefit the State and the IOCs. Without reproducing the American scheme where the subsurface belongs to the land owner, the rent shall indirectly benefit local authorities and communities :

- ✓ More attractive energy prices (oil, gas, electricity)
- ✓ A contribution to economical growth
- ✓ A contribution to direct (related to development and production activities), indirect (linked to other economic activities, but located around the development area) and induced (other industries benefiting from lower prices of energy) local, regional and national employment
- ✓ A contribution to the development of regional and local infrastructure (education, health, transport, sports, culture)

Conclusions

The American shale gas revolution relies on four pillars: knowledge of the subsurface, very favorable mining rules, political support and abundance of oil & gas services in an open and competitive market. This last pillar was a key in the implementation of a factory development model based on the "trial and error" method. It led to impressive operational and low cost performances. Exporting this unconventional revolution out of North America will rely on four major leverages.

Increasing reserves per well can be achieved either by identifying better geological areas (sweet spots) or by improving through learning, completion strategy. Given the strong heterogeneity of large unconventional plays, searching too early for sweet areas during exploration and pilot phases appears highly risky and can lead to a false (positive or negative) evaluation of the play. Sweet areas will appear during the development phase and so they have to be considered as the result of a learning process more than an exploration pilot process. In any case, **the process will remain a factory one** where learning (and therefore relevant monitoring and data analysis) will play key roles to avoid too many unproductive wells.

Optimize well costs remains therefore a key objective to make economic an unconventional development. Fixed DRILLEX (mud, cement, casing, sand, chemicals, fracturing services) playing a key role, standardization, light well architectures, logistics as well as C&P[4] will be of a prime importance to reduce well costs. In Europe with a gas at 10$/MBTU, to reach a pre-taxes IRR of 15% the integrated well cost needs to be in the range of 12,5 MUS$. However, a competitive market of services for drilling and fracturing can only be developed with first and foremost positive political messages.

In North America, the population has been used to living near drilling rigs, fracturing equipment and production facilities for decades. In certain regions like urban Europe there is no real Oil & Gas culture. Hydraulic fracturing, water supply, microseisms and surface impact are seen as a battery of threats by certain stakeholders. Changing this perception and winning over public opinion requires pedagogy, transparency, appropriate communication campaigns and commitment regarding local communities as well as an in-depth review of certain regulations. The game must be win/win so that there is something in it for the majority of stakeholders in the long term. An improvement in the way in which the oil & gas rent is distributed, in particular to local communities, would be a real step in the right direction.

If leverages 1 and 2 remain valid everywhere as the basics of project economics, leverages 3 and 4 will highly depend on the geographic location. For instance, availability of water will become a key issue in desert regions, whereas foot print will be a main challenge in a country where the density of population is high. The same applies for value creation depending if prices of energy are regulated or not.

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