SHALE GAS DEVELOPMENT IN ARGENTINA. A CHANGE TO THE TRADITIONAL E&P BUSINESS STRATEGY.

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EXECUTIVE SUMMARY

Unconventional resources development, especially shale gas, stands as one of the main pillars to the rebuilding of the Argentinean energy system. Even though nature has endowed Argentina with abundant unconventional resources – tight gas, shale gas and shale oil – only the implementation of efficient processes and effective techniques will enable the economic development of these resources.
Exploration, development and production of shale gas mean a striking more intensive activity level, which translates into thousands of shale gas wells drilled and completed with massive fractures in order to achieve the expected production targets. This scale of work can only be attained with a change to the current operational model.
On the one hand, conventional resources development focuses on the determination of resources existence and their size, tailored well design, on-demand materials and services logistics mainly in challenging environments, aiming essentially to maximise recovery and production of hydrocarbons.
On the other hand, unconventionals development, concentrates on the definition of the optimal well locations, to deploy modular campaigns of wells with a standard well design, handling economies of scale and simultaneous operations. All these with the iterative risk assessment and mitigation plan definition made by a multidisciplinary team required to minimise the production cost.

In this paper an analysis will be presented of the level of unconventional resources, specifically shale gas, in the main basins of Argentina, along with a feasibility study as to how to monetise these resources and a set of industry lessons learned to be applied to accomplish the colossal working levels required.

The following aspects will be discussed:

- Unconventional development challenges
- Lessons learned from the manufacturing industry to apply to unconventionals, such as:
  - Economies of scale and bundling of services
  - Strategic alliances
  - Efficient materials and services management
  - Vertical integration of services
- Flexibility in massive operations
- Environment impact management

Keywords: shale gas, unconventional feasibility study, economies of scale, simultaneous operations.

DEVELOPMENT

Unconventional resources in Argentina

There are different types of unconventional resources of natural gas: tight gas, shale gas and coal-bed methane (CBM) (see Fig. 1). Each of them presents its own challenges as to how to produce them, even though they share some common characteristics. In particular, all three of them have a very low intrinsic permeability (see Fig. 2).

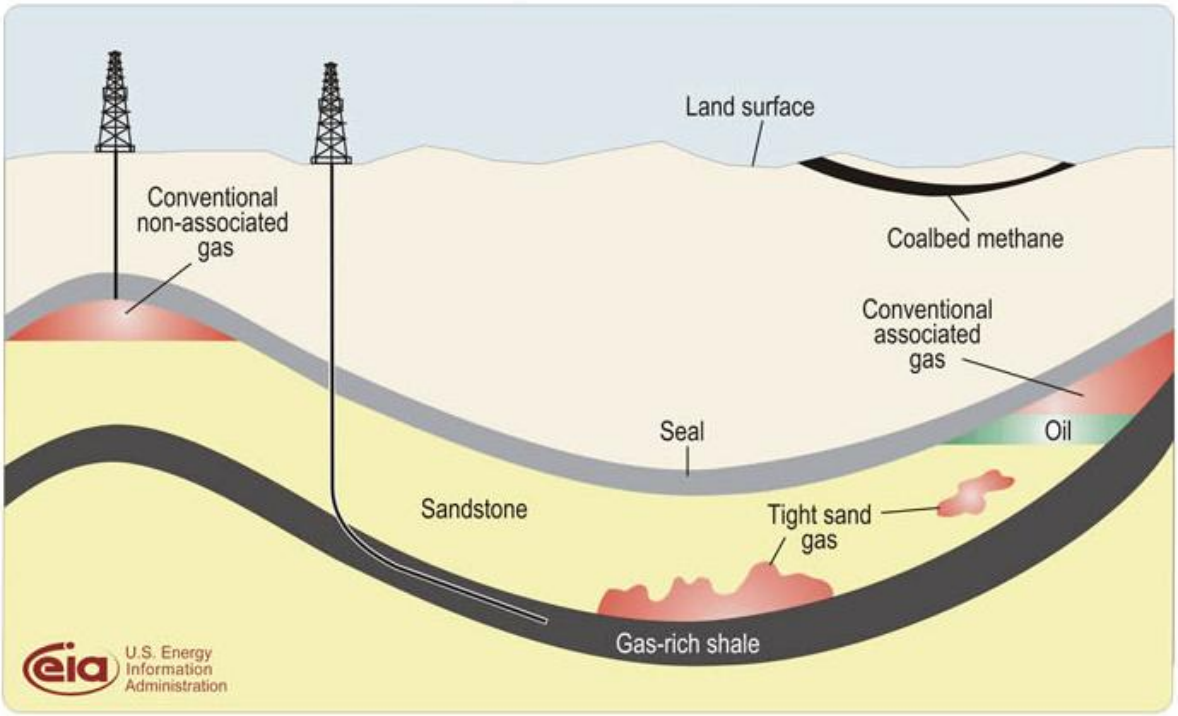

Fig 1 Natural gas sources – Source: US Energy Information Administration – World shale gas World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States, April/2011.

It is not the chemical nature of the gas what distinguishes these three types from conventional natural gas, but the reservoir that contains them. Given this low permeability in the rock matrix, only an improvement in the connectivity between the reservoir and the wellbore will enable commercial natural gas flow.

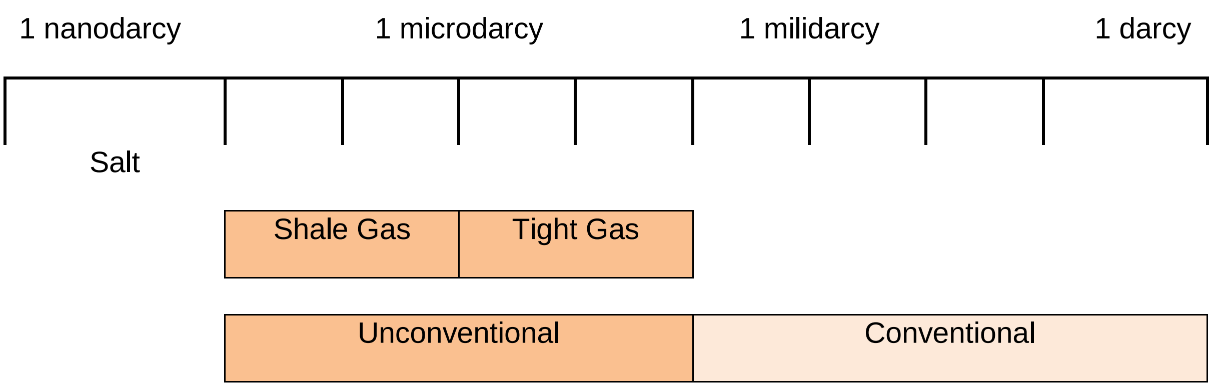

Fig. 2: Permeability of conventional and unconventional reservoirs. Note: 1 Darcy = 9,86923 x 10-13 m2. Source: An introduction to shale gas – 3 Legs resources.

Another common characteristic is the tendency of these resources to be widely dispersed on great geographical areas, filling the pore space of hundreds of square kilometres in areal extent rather than within the tightly defined boundaries of conventional gas reservoirs. This means that exploration risk is very low; the challenges lie in achieving commercial production rates.

Shale gas is extracted from the source rock rather than the reservoir rock. Shale resources represent a particular challenge, because of their complexity, variety and lack of long-term performance data. There is no long history of production from a wide variety of depositional, mineralogical and geomechanical environments, such that analogues can be developed and statistical predictions about future performance can be derived [2].

For the purpose of this study, the only unconventional resources that will be within scope are those related to shale gas. This decision was made given the fact that more than 50% of the national energy matrix is supplied by natural gas and there is currently no official report published on tight gas resources in Argentina.

The US Energy Information Administration (EIA) estimates shale gas technical recoverable resources at 6622 Tcf (trillion cubic feet) in 48 major shale gas basis around the world (see Fig. 3), which is currently 40% of the total recoverable resources of conventional natural gas [1].

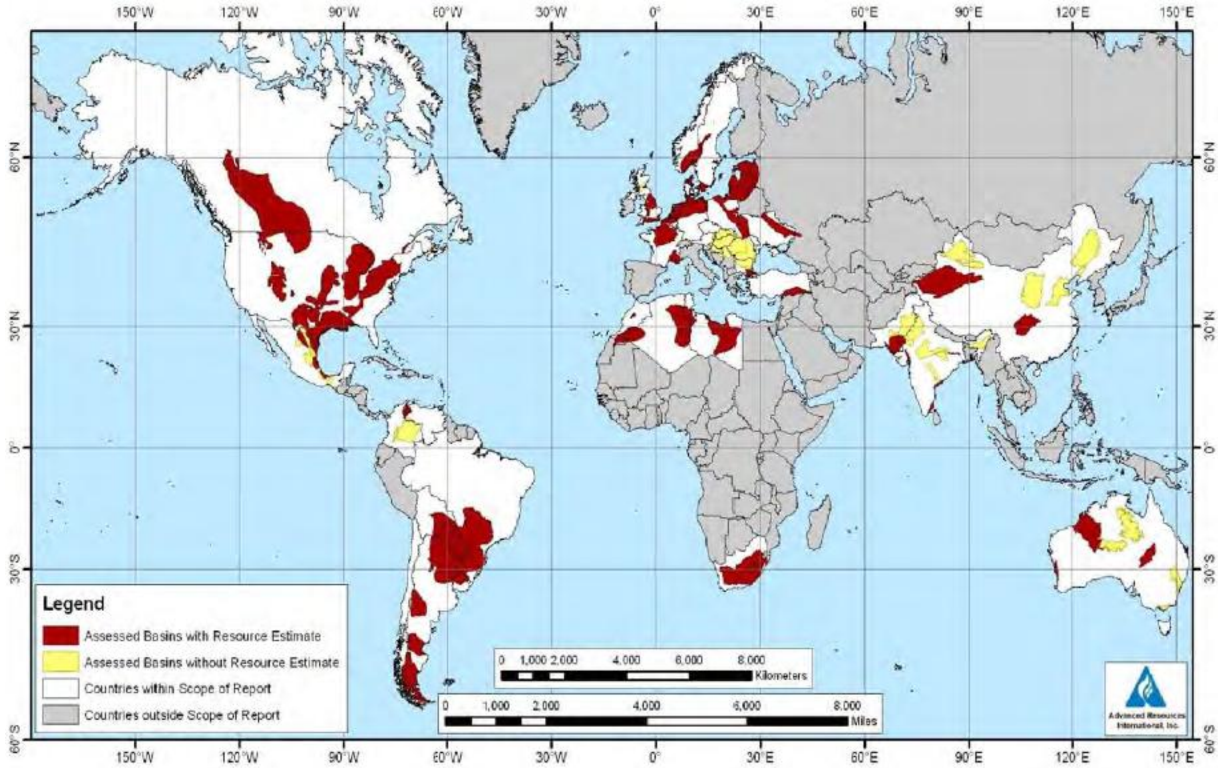

Fig 3 Map of the 48 major shale gas basins in 32 countries. Source: US Energy Information Administration – World shale gas World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States, April/2011.

Argentina with shale gas resources estimated at 774 Tcf, ranks third among countries with similar development perspectives (see table 1).

Table 1: Countries with the greatest shale gas resources.

Country	Recoverable shale gas resources [Tcf]	% of world total
China	1275	19.3
USA	862	13.0
Argentina	774	11.7

Source: US Energy Information Administration – World shale gas World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States, April/2011.

Argentina undoubtedly possess a great potential in shale gas, as can be seen in fig. 4, with 2732 Tcf of total shale gas resources, 774 Tcf of which are considered recoverable. More than half of these recoverable resources are located at the Neuquen basin (see table 2).

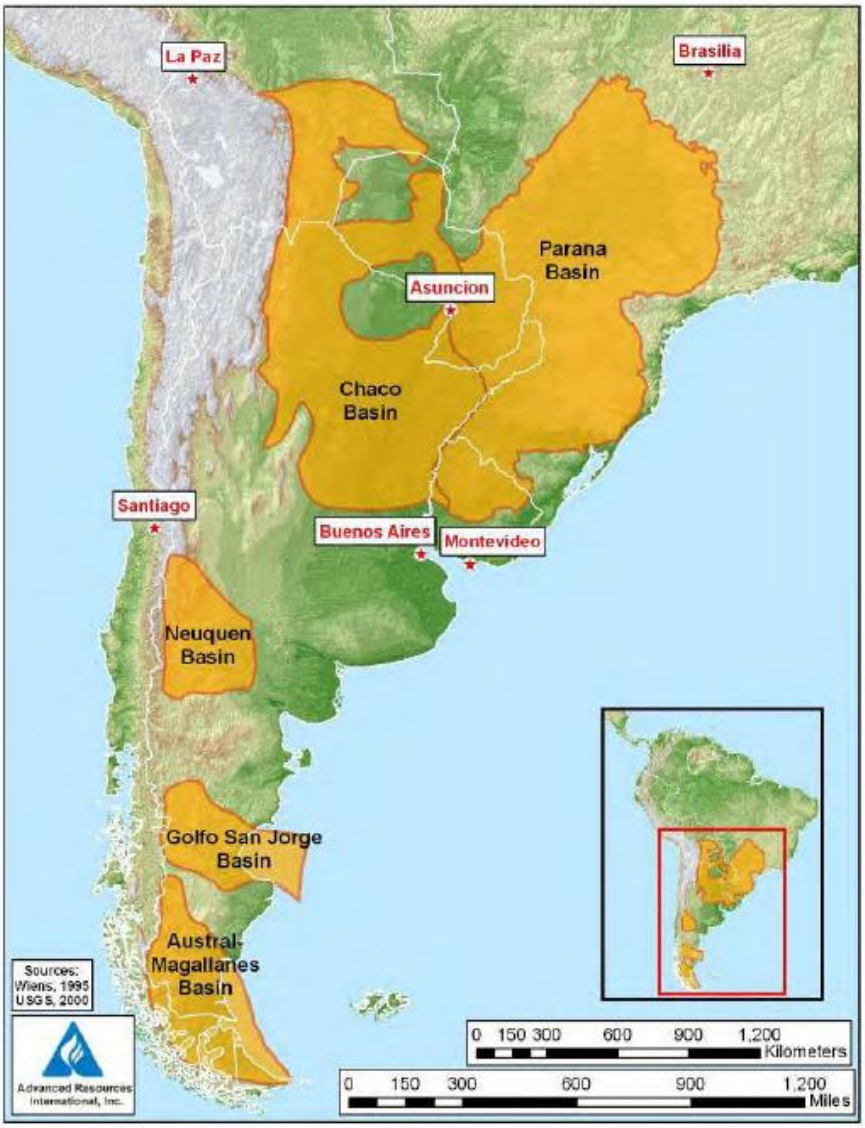

Fig 4 Shale gas basins in southern Southamerica. Source: US Energy Information Administration – World shale gas World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States, April/2011

Table 2: Argentinean shale gas resources distribution by basin.

Basin	Total Shale gas resources [Tcf]	% over total resources	Recoverable shale gas resources [Tcf]	% over total recoverable resources
Neuquen	1165	42.7	407	52.6
Golfo San Jorge	430	15.7	95	12.3
Austral – Magallanes	483	17.7	108	13.9
Chacoparanaense	654	23.9	164	21.2
Total	**2732**		**774**	

Source: US Energy Information Administration – World shale gas World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States, Abril/2011.

Feasibility study of commercial shale gas development in Argentina

Unconventional resources such as shale gas should be implemented learning from the lessons of American operations, where initially a great quantity of wells was drilled following the results of statistical analysis. Many of these wells did not produce the expected results, and even though the development cost was high, these operations were still within the grasp of high natural gas prices. Nowadays, this development strategy changed to a technical analysis of the subsurface in order to find locations with more potential or “sweet spots” [4], where there is a greater probability of finding recoverable resources and of better quality. Another lesson learned is that the development of unconventional resources is only profitable at a large scale, given the low production plateau of the shale gas wells, as can be seen in fig. 5.

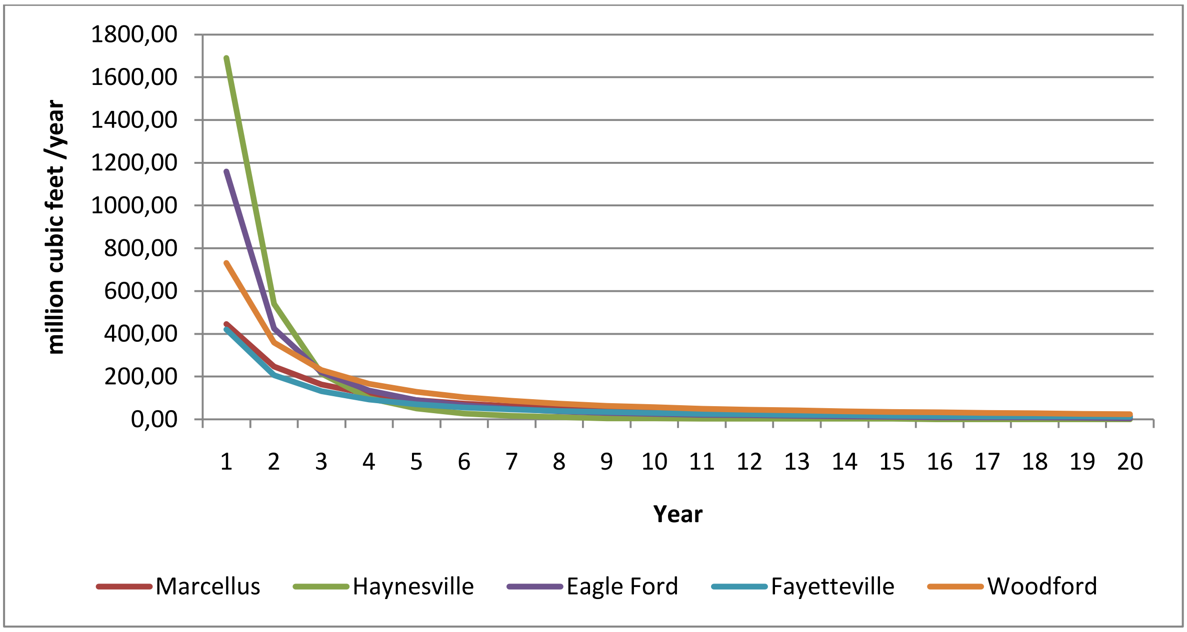

Fig 5. Average production profiles for shale gas wells in major U.S. shale plays by years of operation (million cubic feet per year). Source: US Energy Information Administration – Annual Energy Outlook 2012

This behaviour of high production during the first periods and low but stable during the following periods, as seen in fig. 5, demands a continuous and massive development programme. Due to the need of maintaining the production levels, operators must be able to build enough wells, usually at great scale, as seen in fig. 6.

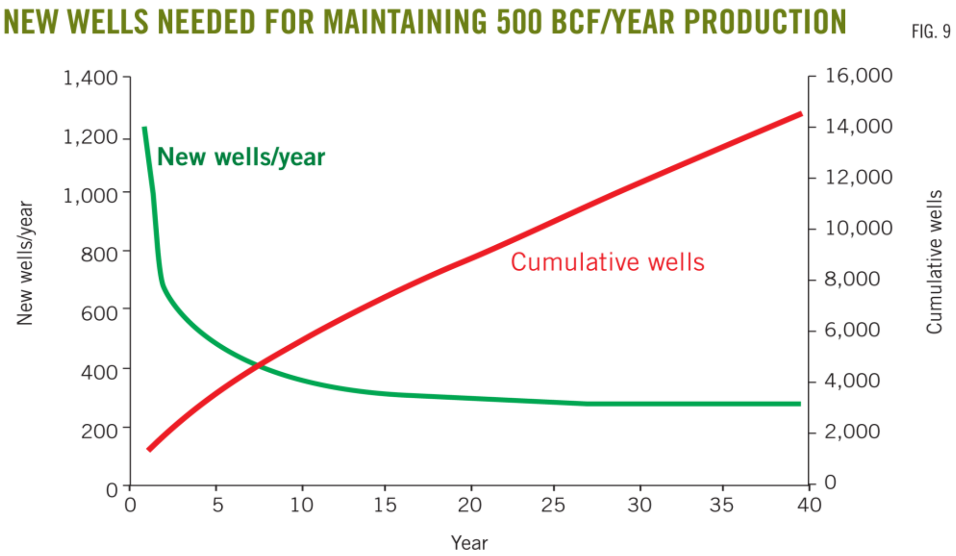

Fig. 6 – Quantity of new wells needed to maintain a production of 500 BCF/year - Fayetteville Basin – USA. Source: “Well production profiles assess Fayetteville shale gas potential” Oil & Gas Journal 04/04/2011

This learning curve must be applied in our geography, since the current economic, financial, market and logistics restrictions in Argentina could hinder shale gas resources evaluation and development projects.

Recoverable shale gas resources estimation in Argentina is significant (774Tcf, see table 1); nonetheless, the potentiality of producing natural gas from these fields is limited to how effective and efficient can operators be in the making and implementation of development plans [3], [5] and [7]. These plans should be diagrammed in such a way that uncertainties associated to production potential are reduced systematically and both technical and operational competences are enhanced in the construction and start-up of wells. In order to achieve these objectives, it is necessary that a multidisciplinary team gathers to study available information of existing wells to define subsurface models (geochemical and geomechanical) and additional information is needed to reduce their uncertainties. In this way, “sweet spots”, where well construction operations can be initiated, would be easier to recognise.

As previously stated, shale gas resources are developed at a great scale; however, to facilitate the confirmation of sweet spots and optimal well design, pilot projects should be implemented. These first wells will provide vital information for both completion design (massive fractures) and well spacing to get the optimal reservoir drainage. According to the pilot’s results, additional development wells will be constructed in these locations, to effectively drain the sweet spot. To have an accurate level of certainty of these results, it is mandatory that well production performance is assessed so as to foresee high water cut or anticipated severe declination.
These periods of analysis could be very extensive from a business point of view; therefore, different scenarios should be established with corresponding risks with the aim of making educated decisions as to how to continue with the development plan. It is very important to identify and assess these risks, given that the construction of unconventional wells presents dangers not only from and operational perspective, but also from a business standpoint, with

the possibility of destroying project value by investing huge amounts of capital in the wrong locations.

To better understand the actual risks during shale gas wells construction, it is necessary to be aware of the challenges that these operations represent according to Argentinean operators experience:

- Complex or poorly understood geomechanics causes inefficient drilling fluids systems, which translate on problems with wellbore caliper and/or well control.
- High cost constructive materials (casing and wellhead) necessary to execute completion operations, mostly high pressure hydraulic fractures (>10000psi).
- Great quantity of equipment is demanded to carry out hydraulic fractures, given the power needed (around 20000 HHP per stage – currently in Argentina 5-6 stages are being fractured per well, while in USA operations could extend to 8-25 fracking stages per well)
- Considerable amount of water and proppant to pump during fracture operations (2000m3 of water and 200ton of proppant per stage)
- Simultaneous operations needed given the quantity of wells to build per location (currently planned in Argentina 4 well per location, while in USA 12 or more wells can be constructed in one location)
- Complex logistics system to be able to transport water, proppant and other materials and services to and from well locations (890-1340 truck trips for a single well location and 5850-8905 truch trips for a 8-well location. [2])
- Operational conditions and the quantity of workforce required during fracking operations increases the risk to people, the environment and/or installations.

In this paper, a feasibility study is presented to determine the break-even shale gas price that allows shale gas resources development at economies of scale, in order to provide between 7.5-18 Tcf to the local market during 20 years of production, considering the following assumptions:

- Given there is currently no official estimations of cumulative production from shale gas wells in Argentina, this variable will be estimated given the average well production profile from 5 basins in USA:

Table 3: Average well production profile per basin, USA.

Basin	First year production [MMm3/year]	Cummulative production (20years) [MMm3]
Eagle Ford	32.81	66.82
Fayetteville	11.89	36.81
Haynesville	47.85	75.60
Marcellus	12.63	44.17
Woodford	20.69	66.54

Source: US Energy Information Administration – Annual Energy Outlook 2012

- Well production horizon: 20 years
- Well spacing: 3 wells / km2
- Quantity of wells to be built: 600 wells/yr during the first 5 years, and then 300 wells/yr to maintain production plateau
- Drilling time: 35 days (horizontal wells), according to local operator experience.
- Completion time: 15 days, according to local operator experience.
- Annual operations efficiency increment: 5% during the first 5 years
- Well cost (drilling + completion): 11 MMUSD, according to local operator experience.
- Facilities associated: 2 MMUSD/well
- Risk: 20%

With all these assumptions taken in consideration, the expected production profiles and CAPEX are as seen in Fig. 7.

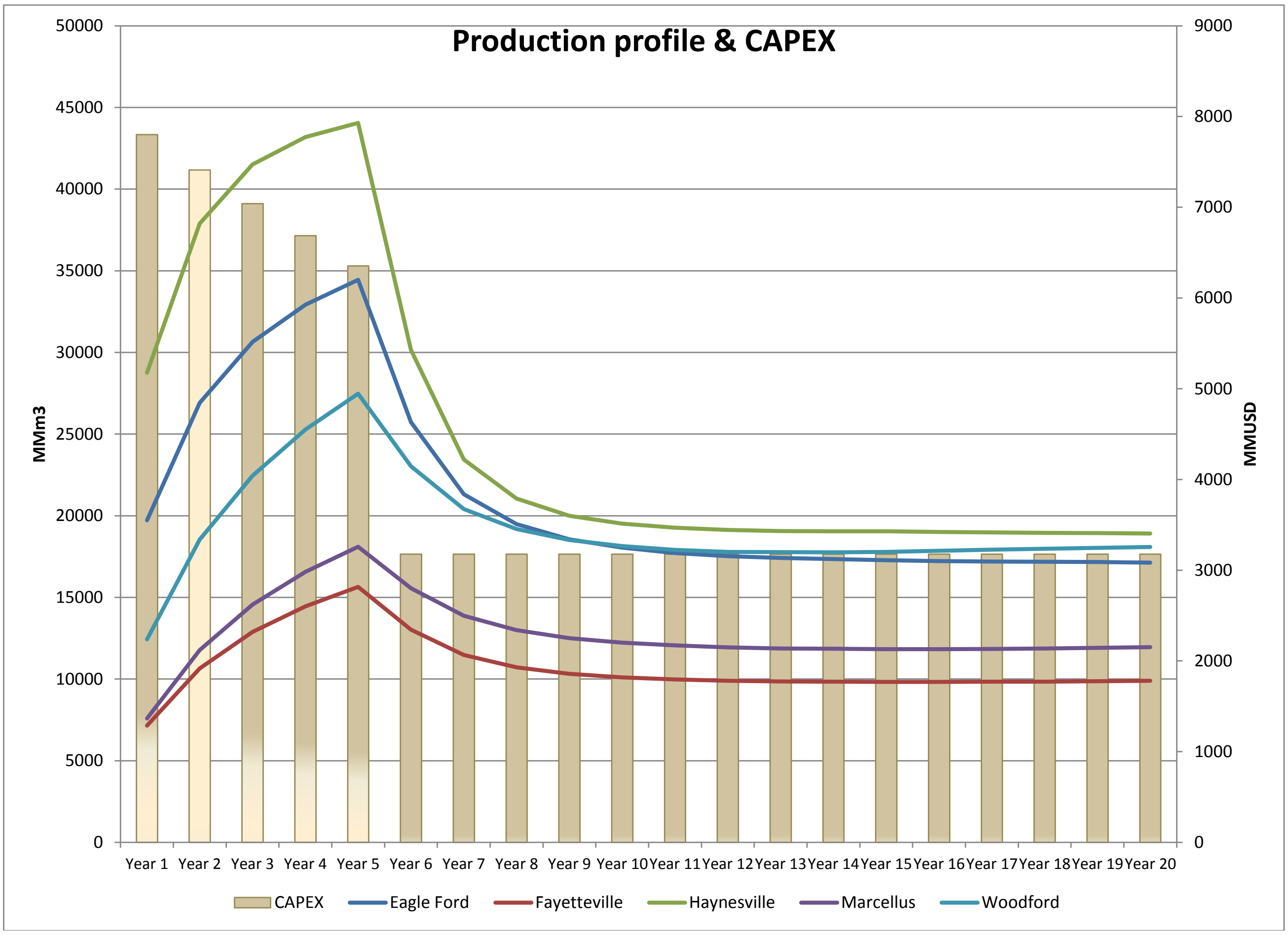

Fig. 7 – Production profiles and CAPEX expected to develop shale gas resources according to given assumptions.

Correspondingly, break-even shale gas prices for each well type are:

Table 4: Break-even shale gas prices.

Well type	Shale gas price [USD/MMBTU]
Eagle Ford	10.57
Fayetteville	20.78
Haynesville	8.70
Marcellus	18.15
Woodford	12.50

The new strategy: staring-up the unconventional factory

The new model is an advancement of the concepts on massive operations. Originally, the industry focused on a factory model, in the search of time and resources optimisation [9]. Nonetheless, this model did not consider the main aspects related to the upstream industry, which is the uncertainty about the existence of these resources in the subsurface. By this

way, a great quantity of wells was constructed, which did not produce the desired outcome (low or no productivity).
Therefore, the new strategy had to consider both aspects: massive operations and flexibility on decision making [5] and [6].

As acknowledged before, shale gas resources development requires massive well construction operations, an equivalent to a “well factory” [6] and [7]. As any manufacturing production, it is based on: the standardisation and specialisation of tasks, “assembly line” process reliability in order to increment the scale of production, and the use of productivity data to enhance the production strategy. Additionally, new approaches are being considered which are aligned to efficient and optimised production (lean manufacturing), as just-in-time stock control, cycle time control and an increasing focus on quality. By this way, what are being sought after are unconventional resources development projects that have investment levels compatible with natural gas market prices.
Recommended practices of this “factory” approach to obtain cost reduction and well construction efficiency are [8] and [9]:

- Economies of scale and bundling of services
- Strategic alliances
- Materials management efficiencies
- Vertical integration of services

Economies of scale and bundling of services

This practice involves different aspects such as multiple well from a single location, under a scheme of simultaneous operations (SIMOPs) [7] with integrated services (bundles) provided by dedicated suppliers; consequently, the impact on the environment is lower.
An integral part of concurrent operations is the stockpiling of consumable materials in advance. This requirement entails a well developed supply management chain, as well as, in some cases, a secure supply from vendors.
By drilling multiple well at the same time, the mobilization costs of services are defrayed over the total number of wells resulting in substantial savings. Moreover, manpower requirements can be better defined and scheduled by the service providers.
Matching the economies of scale model with bundling of services could provide additional savings.

Strategic alliances

A strategic alliance is a relationship between firms to create more value than they can on their own. A significant outcome through a strategic alliance is that the service company could better manage their business knowing in advance the customer needs so as to plan accordingly. To create successful alliances, a company must understand when alliances make strategic sense and must also recognise how to manage them to ensure the business results anticipated.

Materials management efficiencies

Information management can help manage inventories efficiently by ensuring that transactions are carried out quickly. New technologies can also be applied to through information systems established to track purchases, inventories, just-in-time supply processes, as well as overall transactions times from initial order through to payment.
Another aspect is having suppliers manage customer warehousing and inventories through long-term arrangements. Having suppliers well integrated into the business process can provide increased reliability by having the supplier fully immersed in and understanding the operations they are expected to supply to.
Proactive communication between suppliers and producers enhances not only the reliability aspect of ensuring right supplies, but also by ensuring that supplies arrive on time at the

right place. Centralised material receiving and distribution hubs are a key to success when well managed.

Vertical integration of services

Another practice different from the previously stated is vertical integration of services where specific services or suppliers are owned and operated by the oil and gas company to ensure access to equipment and materials as well as to provide stability in the supply chain management of those services or supplies.

This model ensures that:

1. Specialised drilling equipment is properly designed and operated by highly trained personnel. Drilling rigs are commonly owned by the oil and gas company, which are most likely custom designed and equipped.
2. Scheduling the well construction activities is much easier.
3. Supplies of materials needed for the drilling and completion operations can be delivered within a controlled time frame as the suppliers of drilling fluid, additives or fracture proppant are owned by the oil and gas company.
4. Quality control of the materials can be managed more effectively. Water and proppant quality may impact on the success of the completion and stimulation and so consistency is a critical factor.

Needless to say that vertical integration may not be applicable to all unconventional resources development; but it could be possible in those basins where massive operations are needed but little or no oilfield services infrastructure is available.

As previously stated, in an industry such as upstream, the factory model must be implemented in a pragmatic way. That is the reason why the latest trends focus on a flexible factory concept, with three main pillars [6]:

- ***Definition of triggers for course correction***, those milestones that set off changes in well design, drilling plan or capital deployment.
- ***Deploying continuous design improvement capabilities***, which allow to break functional silos and implement a standard and systematic process by which the organisation looks trends and identifies actions
- ***Operating with a rolling planning horizon***, through the segmenting of the field development plan into various phases to create natural points where design changes can be introduced based on the learning from previous phases.

Environmental impact

A good deal of attention has been focused on the high-volume hydraulic fracturing that is an essential component of shale gas development, with a major concern being that the fracturing process risks injecting toxic fracture fluids into shallow groundwater aquifers, which are in many cases the source of fresh water for public use. More broadly, there are concerns about water management and in particular the proper disposal of potentially toxic wastewater from the fracturing procedure.

These aspects are controlled through correct well designs that guarantee that shallow groundwater aquifers are well isolated, and that non-toxic additives are used in fracture fluids, of which service companies must disclose.

CONCLUSIONS

Our feasibility study results show that development plans for shale gas resources are profitable only from 8.70 USD/MMBTU for the best case scenario (Haynesville well type), while a greater price of 20.78 USD/MMBTU would be for the worst case scenario (Fayetteville well type).

Taking in consideration the domestic gas market prices, Argentinean operators should study and determine our own basin production profile type, to determine accurately project feasibility. These developments are highly sensitive to natural gas price, therefore for them to be consistent; there should be a long-term strategic plan that provides sustainability to the business model.

In any case, any given operator at the given assumptions could provide 23.5 to 54.8 MMm3d to the local energy market. This volume could represent a huge addition to the eager Argentinean energy matrix, which would then contribute to growth and development of the country's economy, as well as those of the local communities where these operations take place.

Resources needed to the development of shale gas are significantly greater that those currently available in the domestic market. This increase in resources, materials and equipment demand could only be satisfied in the short-term by foreign suppliers, which could in time provide technical knowledge to develop local suppliers.

Moreover, there will also be a great demand of professionals and technicians with industry-specific knowledge to carry out operations in the field. Hence, the local educational community should be prepared to train and instruct these professional so that these developments could be achievable.

All in all, unconventionals development poses as a hurdle race, along which we need to overcome our own self-imposed convictions and paradigms, in order to arrive successfully to the finishing line.

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