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SHALE RESOURCES IN ARGENTINA: THE VACA MUERTA SHALE FORMATION

A technical, economic and political analysis

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This paper has been prepared for the *Atlantic Basin Initiative*, to be discussed in its Atlantic Energy Forum (AEF) in Mexico City on November 5 and 6, 2015. The objective is to present an up-to-date analysis of the political, economic and technical map of shale opportunities in Argentina, its present day status and its short and long term potential.

Introduction - Brief Analysis

Vaca Muerta is a shale formation located in Neuquén, a mid-west province in Argentina, as shown in Figure 1:

Figure 1. Prospective Shale Basins in Argentina



EIA/ARI World Shale Gas and Shale Oil Resource Assessment

One should note that the North and the Mendoza Basins have not yet been surveyed, even though many geologists think they, too, have much potential. The existence of the Vaca Muerta Formation (VM Fm) has been known for over 90 years, ever since the geologist Charles Weaver (who had been working for the Standard Oil of California) discovered it on the hillsides of “Vaca Muerta.”



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As the hydrocarbons are stored underground in the same very low porosity rocks that generated them, a different technology is required to extract them than that used in more conventional deposits. This is why they are called ‘unconventional reservoirs.’ For this reason, until recent years, this type of formation was not economically exploitable, given that an appropriate technology to produce such hydrocarbons commercially at a reasonable cost did not exist.

Before the middle of the past decade, the availability of crude oil and energy was an increasingly limiting factor in the global economy. The increase in the demand for energy was rising at an average annual rate of 2.2%, and the projections of the Energy Information Administration (EIA) and the International Energy Agency (IEA) were coincident: energy supply would not be sufficient to meet projected demand through 2050. Renewables were therefore indispensable to cover around 50% of demand over that time period.

But a tremendous technological advance changed things in a big way in a short time. The supply perspective was transformed completely by new deep-water, offshore technologies which allowed for the discovery of huge amounts of oil and gas in the US Gulf and all along the Atlantic seaboard of Africa, together with the large *presal* (or ‘sub-salt’ deep water) deposits in Brazil. Furthermore, developments in horizontal drilling, rotation motors and telemetry at the end of the vertical wells, combined with high-pressure multi-stage hydro fracking, using chemicals and propellant material, have allowed us to produce gas and oil from shale formations. This last technology was first developed in the United States and has made possible commercial production in US shale gas formations since 2005, with shale oil production becoming even more significant just a few years later.

From the demand perspective, technology has had the effect of diminishing energy intensity (the amount of new energy demand generated by a 1% increase in the GDP). As a result, the average annual rise in demand fell from 2.2% to 1.2%. This meant 45% less demand by 2050, changing entirely not only the US demand picture but also that of the world. (1)

In Copenhagen in December of 2009 the world community agreed to change the global economic and energy model. Ever since the Copenhagen Agreement, energy availability is no longer the determining factor. Since then, the key constraint has been rising temperature of the planet. (1)



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Vaca Muerta - Amount and quality of its Resources

Having witnessed the great success of shale gas formations in the United States, in 2010, Repsol (a mid-sized, Spanish-based oil and gas company) began to study shale formations in Argentina. The company sent a geologist and engineering team to study the various shale formations in the US. With this fresh knowledge, they reviewed the track record of all the bedrocks of Argentina, selecting a few options. Vaca Muerta was selected as the most promising.

In 2011, Repsol began to explore the Vaca Muerta formation in search of natural gas. After drilling a few exploration wells, Repsol-YPF confirmed in November 2011, first, the existence of gas, and then of oil shortly thereafter. The company then announced the discovery of 927 million barrels of oil equivalent (boe): 741 million estimated barrels of oil and 186 million estimated boe of gas. By February 2012, the company had increased these estimated reserves to 22.5 billion barrels of oil equivalent.

The potential and 'technically recoverable resources' (TRR) of shale gas in Argentina (Vaca Muerta and plus the rest of the country) have been estimated by Advanced Resources International (ARI) at the request of the Energy Information Administration (EIA) of the US Department of Energy, the entity which published the estimates. The first report, which covered nearly 70 shale gas formations in 32 countries outside the US, was published in April 2011. A second report followed in September 2013, extending the research and estimates to the shale oil resources in 41 countries outside the US, covering a total of 137 shale formations.

According to the second report, Argentina has 802 trillion cubic feet (Tcf) of TRR of shale gas --the second largest set of national shale reserves in the world, not considering the US-- and 27 billion barrels of shale oil --the 4th largest national reserves in the world. As can be seen in Table 1, some 73% of these Argentine shale resources are located in Neuquén within two shale formations: Vaca Muerta and Los Molles.



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Table 1. Argentina Shale Gas and Shale Oil, TRR

	<u>Shale Gas</u>		<u>Shale Oil</u>	
	(Tcf)	%	(bn bbl)	%
- Total Argentina	802	100	27.000	100
- Neuquén Province	583	73	19.900	73
- Neuquén Province	583	100	19.900	100
Fm Vaca Muerta	308	52.8	16.220	81.5
Fm Los Molles	275	47.2	3.680	18.5

The TRR of shale gas in both formations are very close in terms of volume, but the shale oil of Vaca Muerta is the largest, and the principal shale resource not only in Neuquén but also in the entire country, representing 81.5% of Neuquén (and 60% total national) shale oil resources. These shale gas resources represent an obvious potential solution for the severe energy (and economic) crisis that has constrained Argentina as a result of the country's increasing lack of gas.

Argentina depends on gas for 52% of its energy. As a result of flawed policies (including excessively low prices, frozen into place for the past 12 years by government control, along with an array of subsidies that enhance consumption), both Argentina's production and reserves have been in continuous decline for years now, even as total consumption has continued to rise, stimulated in the main by gas-generated electricity consumption (which is also subsidized).

Argentina is now spending US\$12bn to US\$15bn per year to import piped gas from Bolivia, along with liquefied natural gas (LNG), fuel oil and diesel fuel -- liquids which arrive by tankers from across the Atlantic energy seascape -- for consumption in domestic power plants. Despite the fact that there is not enough gas to supply the power sector, industry, or the vehicle fleet (under the Compressed Natural Gas Program), government policies have continued to give priority to residential consumption: not only have such prices been frozen by political decision for the past 14 years, but residential consumption has also been increasingly subsidized with each passing year.

Increased imports have covered this growing supply-demand imbalance in Argentina for over 12 years, with import growth limited only by the creeping stagflation the economy has begun to experience in recent years. This situation is not easy to understand given that Argentina has more than enough TRR of gas. It is also hard to believe that the



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Argentine government has billions of dollars to spend on energy imports but none to invest in the future production of its own gas, so as to resolve energy and economic crises. It is well known that Argentina had its own experience with ‘deregulation’ during the 1990s: when subsidies were eliminated and prices allowed to seek their market values. Such measures undertaken today would reduce gas and electricity consumption by around 20%. That might be enough as a first step toward resolving the crises while the development of exploration and production of shale gas resources could also proceed apace.

To produce shale oil, of course, would be the better business proposition, as it would allow for higher profits due to oil’s more attractive international price. Nevertheless, shale oil will not solve the Argentine crisis. This is yet another mistake of the wrong-headed policy of the current government, which has not changed energy policy in the necessary way to facilitate the required E&P, yet at the same time it has induced YPF to explore for oil rather than for gas.

Meanwhile, gas price policy remains the same – with prices frozen for the past 14 years -- while oil is aligned with international prices. It is therefore difficult to believe that government is now subsidizing oil production (with a cost of US\$20/bbl) –some of which is still exported in small amounts—which does not contribute to solving the crisis.

These are the main reasons why only small investments in shale development have been made in Vaca Muerta, while there has still been no exploration in Los Molles.

Companies with Concessions in Vaca Muerta

In Argentina, all minerals and hydrocarbons (and everything else underground) belong to the State -- not to the owners of the land, as in the US. After the Reform of the Argentine Constitution in 1994, the Provincial States are the owners of those resources and the ones who may give Companies the right to explore and produce hydrocarbons. This right to explore and produce is called a ‘concession’ in Argentina: a concession for ‘conventional’ resources has a duration of 25 years and of 35 years for shale and other ‘unconventional’ resources.

Most of the shale resources in Neuquén are found in the same area as conventional resources, only they are located at greater depths. In principle, therefore, all of the fields already have a certain infrastructure available (including gathering systems, crude and gas pipelines, storage tanks, batteries, separation and compression plants, formation water



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disposal, etc). These formations are therefore more feasibly developed economically and thus turned into ;proven reserves.

Vaca Muerta Fm has an extension of 30,000 Km². YPF owns the largest single extension with 12,000 Km² of concessions (40% of the formation total). YPF's extension of concessions in the formation increased significantly after it bought Apache (which previously had held the second largest concession extension with 18% of the Vaca Muerta total¹ -- followed by Exxon (10.8%), Americas Petrogas (8.5%) which recently sold most of its fields and rights to Tecpetrol, Shell, EOG (1%), Total and some others with smaller extensions.

Rich in resources and low in investments: The political map of Vaca Muerta

Argentina is currently in an energy crisis, which produces a drain on, and lack of, dollars, provoking in turn a crisis in the external sector. This implies great opportunity in the huge amount of shale resources underground. The current Government is responsible for the energy crisis given 12 years of wrong-headed energy and economic policies, the absence of legal and regulatory certainty, and the widespread breach of the privatization contracts of the 1990s.

More than 20 years after Argentina achieved energy self-sufficiency (and thereby achieving 'energy security'), the current government managed to lose it by keeping gas and electricity prices very low, when natural gas supplies 52% of energy demand. The government has also taxes energy exports for most of the last 10 years, increased subsidies to gas and electricity consumption still further, presided over an average annual inflation rate of 20% for the last 8 years, and maintained an exchange rate behind inflation (as an anchor for the latter).

Companies therefore have not be able to be profitable enough to justify undertaking required investments, while net profit and profitability have been very committed during this time. Therefore, the government created the crisis by stimulating consumption with low and frozen prices and discouraging production; and it provoked even more imbalance by increasing subsidies. .

The energy policies followed over the last 12 years have also been responsible for the recent rise in Argentina's energy intensity (EI). Indeed, Argentina has moved in the

¹ According to Press publications, government pressured Apache to sell the Company and the rights on more than 20 concessions to YPF ("La historia secreta de las presiones del Gobierno a Apache para que venda su yacimiento a YPF").



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opposite direction of the other major countries of the world in this regard. The country has ignored the warnings of many experts, allowing consumption to grow, the equivalent of increasing energy imports that have only been slowed by recession.

Argentina will shortly hold presidential elections, and two months later the government will change. This prospect has renewed expectations of changes in energy and economic policies and, in turn, for improvements in the investment environment.

Argentina simply cannot continue to spend more the US\$20 bn annually in consumption subsidies and another US\$15 bn per year to import energy (more than US\$35 Bbn annually in total) while at the same time maintaining that the country does not have enough money to invest in shale gas resources so as to be able to extract its huge riches. Therefore, expectations are for coming policy changes which would shift such energy spending into energy investment within the context of an improving investment climate.

Antonio Brufau, the former president of Repsol-YPF, announced an Investment Plan at the end of 2011 (when he still had the support of President Mrs. Kirchner) of US\$28.5 bn over five years to begin exploring Vaca Muerta. However, after the expropriation of 51% of the company by the Argentine government, the new CEO of YPF, Mr. Galuccio increased the Investment Plan to US\$3.5 bn. But YPF is still the largest investor. Other companies are waiting for a more secure environment and better conditions to invest.

The End of the Cycle for the Current Administration: A Change of Expectations

The main reason why Vaca Muerta and Los Molles have not yet received sufficient investment (while counterpart shale formations in the US have) is the lack of rules and therefore of investor confidence in the economy in general and the sector in particular. This lack of investor confidence is articulated concretely by over taxation, lack of legal and regulatory certainty, and restrictions on repatriation of dividends to the parent headquarters.

However, a change in the administration will make possible the necessary changes in policy. Elimination of subsidies and a return to market prices would diminish consumption by around 20% (following the experience of deregulation in the 1990s). That alone would be almost enough to balance short term gas supply and demand and eliminate the need to import energy. At the same time, the country could convert its current spending policy into an investment plan.

In the long term, further changes will be needed to regenerate confidence in the energy sector and in the boarder economy.



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Congress should enact the necessary laws so as to reaffirm the country's decision to return to international financial markets by complying with all international practices, reaffirming itself as a member of the G 20, and recommitting to its alliance with the OECD countries -- rather than with China and Russia which may serve as convenient commercial partners but not as strategic allies for Argentina.

Comparison between Vaca Muerta and Eagle Ford

In its second report, the EIA states: "The potential of Argentina in shale oil and shale gas is the most prospective outside the US; in particular the Province of Neuquen." Former Deputy Secretary of Energy of the United States, Daniel Poneman, visited Argentina in May 2014 to sign a Strategic and Technical Cooperation Agreement between the two nations, to develop the exploitation of these shale resources and the environmental regulatory framework for fracking. When he visited Vaca Muerta, he publically stated that Vaca Muerta is one of the best shale formations in the world and as prospective as Eagle Ford.

The thickness of Vaca Muerta formation is between 180 and 600 meters, compared with the 60 to 180 meters of Eagle Ford. This deeper thickness in Vaca Muerta allows, in some cases, for the use solely of a vertical well, avoiding the need for costly horizontal sections, thereby reducing costs significantly and making more possible and profitable the extraction of these shale resources.

Shale formations are anisotropic, in that they do not have same properties in all directions. They are heterogeneous and their geophysical characteristics may vary greatly over short distances. This is why a larger E&P investment is required: as production may vary greatly among fractures -- and up to 50% of them may turn out to be unproductive -- horizontal sections of 1,500 meters and even longer may often be required, depending on each particular formation, to increase the probability of making them productive.

The productivity of neighboring wells may vary greatly even at different depths. This is the reason why it is often necessary in such formations to carry out a Pilot project after the Exploration phase has concluded, in order to gather and collect more knowledge and information and make the final adjustments to the Investment and Development Plan.

This was the case in the "Loma Campana- Loma la Lata Norte" field in Vaca Muerta, developed by YPF in association with Chevron. After drilling more than a 100 exploration wells, the two companies had to invest US\$1.36bn in a Pilot project in order to confirm exploration data and adjust the Investment and Development Plan, before declaring Loma Campana- Loma la Lata Norte the first commercial shale oil field outside the US.



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Investment is the precise answer to the question “Why is Eagle Ford a reality while Vaca Muerta remains only a potential? This answer is underlined by the experience of the US Department of Energy which finds that the two formations have similar prospectives. Poneman highlighted the quality of Vaca Muerta when he publically declared that “Vaca Muerta is a first class shale resource worldwide,” and that “Argentina may experience an energy boom similar to the US, which will change its economy and level of competitiveness.”

The only reason why Eagle Ford is a reality and Vaca Muerta still just a promise, has clearly been the difference in investment. While in Eagle Ford investment was US\$30bn just for the year 2013 alone, in Vaca Muerta, investment came to only US\$1.2bn in the 4 years from 2010 to 2013. This has translated into 260 and 33 wells drilled per year, respectively, with an overall total of 1,040 wells have been drilled in Eagle Ford versus just over 160 wells drilled to date in Vaca Muerta.

It is well known in the shale industry that the only way to develop knowledge and experience – to move along ‘the learning curve’ in each concrete formation) is to invest in exploration. This happened in Eagle Ford, and remains the principal reason why its promise is now already a reality. This explains why Vaca Muerta is still only ‘potential.’ While we will elaborate on the reasons for this further below, we can be sure that Vaca Muerta will one day become as a real success as has been Eagle Ford -- as soon as sufficient investments arrive. It is just a matter of investment and time.

The comparative analysis of investment in both formations is the best proof of the enthusiasm in investing in Eagle Ford, and the total lack of interest in doing so in Vaca Muerta.

Since 2013 -- with the arrival of Chevron and the eventual arrangement between the Argentine government and Repsol for the payment of the 51% share in YPF that had been expropriated -- most of the major oil companies of the world have become very interested in the hydrocarbon potential of shale bedrocks, making so called ‘unconventionals’ one of the new pillars of the world’s new ‘energy paradigm.’

YPF is the company that has invested the most, and therefore knows the most, about the Vaca Muerta formation. In a presentation to investors in Houston, YPF’s president said that “there is no doubt Vaca Muerta is bigger than Eagle Ford and Bakken.” His opinion is even more valuable, given that he worked at Schlumberger before rejoining YPF.

Comparison between TRR of shale in Argentina and the Presal in Brasil

The best estimation of the resources of the Brazilian *presal* is 100 billion (bn) barrels of oil equivalent (boe) (10bn boe alone in Libra, the largest field. In contrast, Vaca Muerta has 16.2 bn bbl of TRR in shale oil, and 308 trillion cubic feet (tcf) of shale gas (equal to 71.13 bn boe in total).

However, the total shale resources of Argentina (802 Tcf of TRR of shale gas and 27bn bbl of shale oil) come to 170 bn boe, or 1.7 times larger than those of the presal in Brasil. (2) It is important to keep this in mind as an indicator of real relevance and potential impact of Argentina shale, particularly given that the discovery of the *presal* changed the entire global vision and prospectus of oil and gas hydrocarbon availability.

Table 2 compares the resources of Presal with the TRR of shale resources (in terms of boe) of Argentina, along with their main characteristics and corresponding investment plans.

Table 2. Comparison of the Brazilian *presal* with Argentine Shale Potential

	PRESAL BRASIL	ARGENTINA NO CONVENC.	
Reservas Estimadas, MM Bbls	100.000	170.000 (27 Bill. + 143 Bill.) (*)	1,7 Presal !!
El costo Pozo terminado, MM US\$	80 - 120	Inicial: 10 - 11; Actual: 7 - 8 Futuro: 5 - 6	
Inversión Realizada (2008 - '12), MM US\$	112.500	E&P ?	
Plan (2013 - '17), MM u\$	237.000 Financiados	35.000 Sin Financiar	
Profundidad, mts	5.000 a 8.000 en el mar	1.800 a 3.300 on shore	
Costo Infraestructura, MM US\$	Muy elevado (300 Km costa adentro)	Ya existente y en operación	Cias.Servicios
Espesor Formación, m		200 - 600	EEUU < 200

(*) Sin Cuyo y NOA.
Fuente: elaboración propia (OTC 2013, Informe US-DOE)

Own source and elaboration.

Furthermore, Argentina’s shale resources possess several advantages. First, all of Argentina’s shale resources are onshore, making exploration and production technology much cheaper.

The cost of drilling and finishing a well in a shale formation is US\$6mn to US\$7mn, while in the presal – some 300 km away from the coast line and 5,000 to 8,000 meters below the surface of the ocean – the cost of drilling and finishing is between US\$80mn to US\$120mn per well.



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In addition, Argentina's shale resources are located practically in the same areas as its conventional hydrocarbon resources currently under production. This implies the much of the needed infrastructure already exists.

On the contrary, in the deep offshore presal fields no physical infrastructure pre-exists the presal platforms. This starting points makes it more difficult to declare the presal fields as commercial (or proven) reserves, given that the break-even point will be higher. It also takes much longer in the offshore to build the required infrastructure for evacuating gas and oil production. Furthermore, the workers, as well as all materials and supplies, must be transported to and from the coastline. Not only is the cost of drilling in the Brazilian *presal* higher, but such offshore drilling must also be conducted from a marine platform. There are 120 such platforms operating in the *presal*. When Petrobras does not have enough of its own platforms, it faces a per platform rental cost of about US\$480,000 per month.

Such capex and opex differences are quite important, as they indicate that it is more feasible to convert resources into reserves in Vaca Muerta and the shale formations of Argentina than in the Brazilian *presal* (which, at the time it was discovered, created great and rising expectations in Brazil, suddenly the 9th largest economy in the world and the country with the 6th largest oil and gas resources.

However, both the Brazilian *presal* and the Argentine shale have generated environmental controversies, although of a different order: in one case, the potential risk is of polluting further an already faltering sea; in the other, the risks are those potentially posed by the technique of 'fracking.'

Some environmentalists see as a risk the multi-stage hydro-stimulation in shale formations, stemming from the intensive use of water mixed with chemicals at high pressure. In this case of 'fracking', the principal risk would be potential contamination of the area's drinking water from the chemicals or toxic waste water from the formation. However, in Vaca Muerta, the drinking water is found at depths no greater than 300 meters, while the shale formations are found at depths between 2,300 and 3,200 meters, leaving a physical barrier of 2,000 to 3,000 thousands meters of many impermeable layers of rock in between, preventing contact (see Figure 2).



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In the *presal*, however, such incidents may have very different implications.

Finally, the investment plans of the Brazilian *presal* and Vaca Muerta shale differ in key ways. The investment plan of Petrobras for the 10 year period 2007- 2016 calls for US\$352 in investment. According the information provided by the Commercial Officer of the Brazilian embassy in Buenos Aires, the company has invested US\$210bn in just the four years from 2010 to 2014. This demonstrates that such huge investment challenges can be in Latin America.

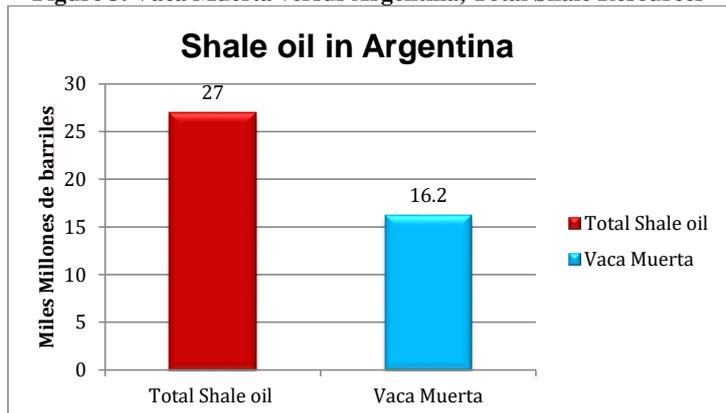
According to an estimate from the Financial Times (4), adjusted with the new information offered in the EIA's 2nd report, around US\$300bn in new investment will be required in order to produce all of Argentina's shale resources. This would imply that US\$167bn will be required in Vaca Muerta alone. A 10-year investment program designed to eventually produce all of Argentina's shale resources would require investment of US\$30bn per year. A 10-year investment program focused only on the shale resources of Vaca Muerta would require investment of US\$16.7bn a year.

Such investment levels are feasible, as the previous experience of Eagle Ford and the Brazilian *presal* investment program both have demonstrated. Therefore, investment requirements do not represent a barrier to Argentine shale development. The only pre-requisites still required to recover the international confidence needed to induce such large investment flows are (1) a sense of legal security, (2) a return to market prices and (3) a predictable management of economy. Fortunately, the next government is widely expected to address these issues.

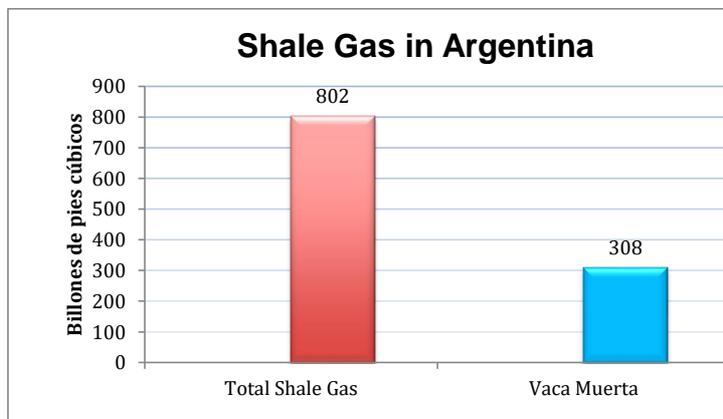
The Importance of Vaca Muerta and Neuquen Resources for Argentina

As mentioned above, Neuquén holds 73% of the total shale resources of Argentina in two distinct shale formations, Vaca Muerta and Los Molles. Both of have similar prospective in shale gas, but not in shale oil: Vaca Muerta contains about 60% of the shale oil of the entire country (82% of the province) and 38% of the country's shale gas (Figure 4).

Figure 3. Vaca Muerta versus Argentina, Total Shale Resources



Source: EIA/ARI Report. Note: Total Vaca Muerta: 30.000 km2. YPF/Apache 13.500 km2. LC: YPF-Chevron 395 km2 (1,2%).



Source: EIA/ARI Report. Note: Vaca Muerta 70bn boe.

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This field had been the most explored at the time 51% of YPF was expropriated from Repsol in April 2012. There had also existed previous partnership talks for exploitation with Chevron.



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When the Loma Campana Memorandum of Understanding was signed in 2013, YPF had more than 100 wells drilled, 50 finished and an Investment Plan and Pilot scheduled to make final adjustments in Loma Campana, a field of 395 Km² (1,2% of the Vaca Muerta area).

From a national interest standpoint, increased gas production is required to resolve the domestic energy crisis. However, the Loma Campana project is designed to produce shale oil. So, its objective, firmly pushed by government, is to make money; producing crude oil is a more profitable business, especially for those who kept the 49% of shares of YPF that had not been nationalized). But it does not help to solve the energy crisis.

Despite the country's difficult conditions (including legal and economic uncertainties, restrictions on the repatriation of dividends, and high inflation rate with its negative impacts on the domestic costs) and Repsol's threat to sue to any company that is associated with YPF to exploit areas that the company considered its property, Chevron finally signed the agreement to invest 50% of the US\$16.3bn project in this area, once the national government granted all their demands. This demonstrated a clear sign of the interest in Vaca Muerta on the part of US major companies.

Unfortunately the Argentinian government took another wrong turn: instead of modifying its global policy, it merely issued a "tailor-made drawing country for Chevron, by Decree 929/13", giving Chevron the legal and economic certainties than it required in order to sign the Agreement with YPF.

The results of the Pilot were excellent, confirming what was expected. YPF- Chevron declared Loma Campana commercially exploitable -- with 31,000 boe per day of production in July 2014⁽⁵⁾ -- before finishing the investment program of US\$1.14bn in the Pilot.

As a result, Loma Campana became the first commercial shale field outside the USA. YPF then announced it the second largest field in importance by production in the country, just behind Cerro Dragón, with two "sweet spots" (higher production areas): one with vertical wells (which doubles production), and the other with horizontal wells.

So after many years of continuously declining production, YPF increased its gas production by 35.4% and its oil production by 12.9% just by exploiting 1.2% of the Vaca Muerta area. This production surge reversed 15 years of production decline in Neuquen province and provided clear evidence of Vaca Muerta's potential.



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It is easy to imagine what might happen if Argentina made the right decisions to liberate the full potential of the other 29,609 Km² of Vaca Muerta (98,8% of the total VM area), along with all shale resources of the country. Argentina could reproduce the shale production boom of the US: major companies such as Exxon, Shell, EOG, Total, etc. are waiting to invest on a large scale, if economic and legal security is perceived.

This will not be easy and will require enormous investment and effort; but it is possible. Such an Argentine shale boom would also result in an important production cost reduction that will impact positively upon the competitiveness of the Argentine economy.

Once the Pilot was completed in Loma Campana, the YPF-Chevron Investment Plan for US\$15.36bn foresaw the massive 14 year development of the field starting in 2014. Drilling 1,188 vertical wells and 489 horizontal wells is expected to maintain a plateau of approximately 75,000 barrels per day of oil production and an associated gas production of 3.4 million m³/d (20,900 boe/d) for 9 years. (6) These production forecasts suppose a total recovery of 794 million BOE.

Table XX presents a summary of the expected investments, operating costs and wells to be drilled during the life of the project, including the Pilot. (6)

Table 3. The Loma Campana Project

	Pilot Year 1	Development Years 2 a 35	Total Project
Investments , US\$m	1,146	15,360	16,506
Operating Costs US\$m	776	9,364	9,441
Production , mn boe	11	782	794
Well Numbers	115	1,562	1,677

Currently this project is the only important effort in Vaca Muerta to develop its huge richness. Yet, the investment levels are very poor compared with Eagle Ford, where the investment was US\$30bn in just one year, 2013. In addition, YPF only has one other agreement with Dow Chemical for a Pilot of US\$500mn to explore for gas. YPF also signed a Memorandum of Understanding with financial partners including Gazprom (although YPF needs technological partners), which has publicly declared that its main



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objective is to develop knowledge and take advantage for the exploitation of the shale resources in Russia.

In summary, the great potential of Vaca Muerta is clear: a relative low investment to develop a Pilot in a very small portion (1.2% of its area) has resulted in the 2nd largest oil field in the country and an important increase in oil and gas production.

The success of this project allows us to imagine what would happen if government policies change with government and a friendlier environment for investment is confirmed. If Argentina is able to recover the confidence of investors and the international community, the expected production “boom” of Vaca Muerta will probably occur very soon. That would be the prelude for developing the large gas resources of Los Molles.

To develop these resources -- and to reproduce the US shale boom and its impact on the economy -- Argentina needs capital, knowledge and technology. At the same time, the US is the world’s major exporter of technology and capital and the only country that has developed shale technology and the required expertise. Prior to these recent developments in Argentina, the US was the only country in the world with commercial shale production.

Last year the US expressed its interest in cooperating with Argentina to develop these shale resources. In May 2015, the US Deputy Secretary of Energy, Daniel Poneman, was sent to Argentina to sign a Strategic and Technical Cooperation Agreement to develop these resources and articulate the necessary regulations. Although the Argentine government signed the agreement, it did not put it into practice. Instead, the government preferred to sign and develop strategic and financial agreements with Russia and China to develop nuclear and hydro power, clearly revealing that the government does not have a strategic vision or a National Interest Plan, but rather just a short-term vision.

Future and Long Term Perspectives

At present, the economic and legal risk in Argentina is higher than the geological and technological risks, characteristic today of the broader global oil and gas industry. As such, the time has come to change course and to put this Technical Agreement with the US into effect. The forthcoming Administration is expected to correct this over the next few months. If it can manage to do so, and make the right decisions to recover confidence in the economy, Argentina could soon witness a production boom that will transform the Argentine economy and turn the country into Argentina into an important crude oil and gas exporter.



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Argentina has presently two big concerns: (1) to solve the domestic energy crisis and to recover its energy self-sufficiency, and (2) to make the appropriate decisions that will encourage enough foreign investment to fully develop Argentine shale. The energy crisis can be resolved relatively quickly, provided that the new Administration reduces the energy intensity by suppressing subsidies, allowing market prices for electricity, pushing the development of gas.

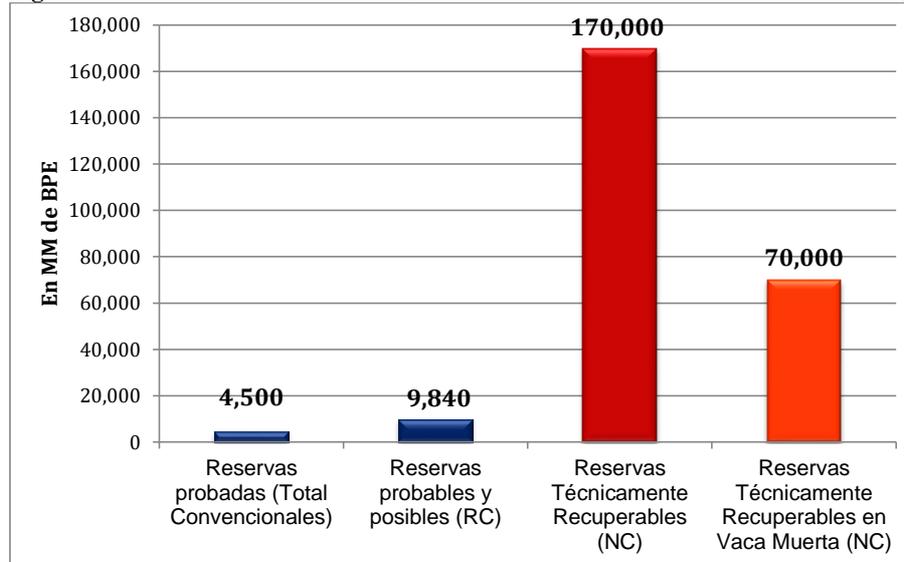
Furthermore, by the year 2050 renewable energies will be mature enough to take over the current role of hydrocarbons as the main vector of the economy and its major source of energy. This would imply that hydrocarbons would begin to lose their relative market value during the second half of this century. Therefore, national interest would suggest the need to maximize the net present value of Argentine hydrocarbons by undertaking to produce most of the shale TRR before year 2050.

To achieve this, the forthcoming Administration must eliminate economic and legal uncertainty as its top priority. It must also articulate and implement the incentives needed to support an Investment Plan of US\$300bn over 10 years, or US\$30bn a year. Brazil has already demonstrated that such annual levels of hydrocarbon investments can be generated. Indeed, the US shale industry generates US\$150bn per year in investment in order to maintain its shale production.

To attract such investment levels, Argentina will need to make the firm commitment to return to more predictable economic foreign policies, to ensure a minimum of legal and regulatory security, and to rely more market prices. Only under such circumstances, will companies like Exxon-Mobil, EOG Resources, Chevron, Shell, Total and others begin to execute their investment programs for Vaca Muerta. The US has expanded its gas and oil production by 10 fold in just 5 years: if Argentina is able to generate the appropriated conditions, in just a few years to can become an important oil and gas exporter.

Figure 4 presents a comparison between Argentina's conventional reserves (proved, probable and possible) and its total unconventional resources, including Vaca Muerta.

Figure 4. Conventional Reserves and Unconventional Potential



Source: Energy Secretary and EIA/ARI Report

The renewed expectations are a great opportunity for the forthcoming Administration to change its wrong-headed policies and liberate the full investment potential of the private companies that operate in Argentina. During the Argentina Oil and Gas Exposition 2015, the President of YPF announced that in a recently drilled (identified as “Loma Campana 99”, YPF-Chevron have found a “real super well of shale oil”, with an initial production of 1,630bpd it is one of the best initial production performances of an Argentine oil well in the last several years.

YPF’s technicians believe that the experience with the Loma Campana 99 well might change the “production pattern” of shale oil in Vaca Muerta. YPF drilled 5,350 meters deep (the standard has been 2,200m to 3,200m) and 2,000 meters of horizontal length (typically only 1,500m), with multiple (28) hydro stimulations (typically only 10 fracking stages). All of this in unprecedented, and because of the promising results, YPF is now planning a well with 35 fracking stages in order to continue to build its learning curve.

The announcement also claimed that YPF now produces more than 50,000boe per day in Vaca Muerta, nearly 10% of YPF current production levels -- a threshold objective that YPF had set for this year. The YPF president also added: “I cannot say we have all the



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technology we need to make a well like this in Argentina. We cannot say either we understand all shale exploitation; what we can say that we have a showcase that allows us to exhibit Argentina as the country with the most development potential, after the USA. And this is not something hypothetical, as we have proved it.” (7)

Argentina will need to keep in mind what Petrobras has claimed about the development of Brazilian *presal*: “Everything started with an idea of those who believed that there are not barriers but rather opportunities”.



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Notes

- 1- World Energy Outlook 2011.
- 2- “La solución a la Crisis Energética son los Hidrocarburos no convencionales” Raúl Parisi, CARI - 24 de Julio 2013.
- 3- “Environmental Recommendations”, Geology and Mines Institute of Spain. January 2014.
- 4- “8 things Argentina must do to win over energy investors”, Financial Times 09/25/12
- 5- Democracy and Development Seminar, August 12th 2014. YPF Manager on non-conventional hydrocarbon’s announcement.
- 6- Documento de YPF a la Legislatura de Neuquén, para aprobación de la Ley Provincial que autorice las condiciones del Acuerdo YPF- Chevron.
- 7- La Nación Newspaper; October 9th 2015.

Annex I

The Technically Recoverable Resources (TRR) of Argentine Shale and the Quality of the Vaca Muerta Formation

Both the EIA’s 1st and 2nd reports pointed out the excellent prospecting characteristics and quality of Vaca Muerta in comparison with Eagle Ford in the US, considered the best shale formation in the world.

As seen in Table 2, Vaca Muerta has a ‘combined success factor’ (CSF) of 60 (which considers the geological risk of the formation). This is an excellent rating, given that Vaca Muerta has still experienced very little investment, and considering that a CSF of 100% is the rating that corresponds to a field in production with proven reserves.

The ‘recovery factor’ in both Vaca Muerta and Los Molles formations is 35% -- is also remarkable. Recovery factors (which measure the response of each formation to fracking) are typically between 20% and 30%, with 35% considered to be exceptionally high. In contrast, the recovery factor drops to 15% in those cases where exploration and seismic information is very poor and the risk is high, as is the case in the Chaco-Paranaense Basin (which is dismissed in the 2nd report).

Table 2- Risk and Recovery Factors of Argentine Shale Formations

Cuenca	Formación	Gas in Place	Shale Gas			Shale Oil
			Factor de Éxito Comb.	Factor Recup.	RTR Gas (Tcf)	Bill bls Oil
Neuquina	Los Molles		50%	35%	275	3,66
	Vaca Muerta		60%	35%	308	16,22
	Sub Total				583	19,9
San Jorge	Aguada Bandera		20%	20%	50,8	
	Pozo D- 129		24%	25%	34,8	0,5
	Sub Total				86	0,5
Austral- Magall.	L. Inoceramus		25%	20%	129	6,6
	Magnas Verdes		25%	25%	3	0,01
	Sub Total				132	6,6
Chaco- Paran.	San Alfredo		12%	15%		
TOTAL					802	27

Fuente: Tablas A.1 y B.1 Informe DOE (no se evaluaron la C. Cuyana y del Noroeste)

ARI/EIA Report 2013

It should be noted that TRR are risk resources and are affected by the recovery factor. This means that they count as existing resources, capable of being produced with existing technology. Such TRR resources only need to be economically exploitable in order for them to be converted into proved reserves. This is why the existence of previous hydrocarbons infrastructure is so important -- as is the case of Argentina's Vaca Muerta, but not in the Brazilian *presal*.

With more geological information (including extension area, thickness, porosity, pressure, natural faults and carbon content) resulting from further exploration, the 2nd ARI/EIA report reduced the risk by raising the combined success factor of Vaca Muerta to 60% and of Los Molles to 50%. In turn, shale gas TRR rose by 43% in Neuquén (28% in Vaca Muerta and 65% in Los Molles) in the 2nd report, which for first time incorporated into the estimates shale oil resources, especially significant in Vaca Muerta.

It confirmed and revealed that Argentina has not only enough shale gas but also shale oil resources, and is able to solve its energy crisis and reproduce the US "boom" in production. But in order to do so, it has to make the right decisions. It also ratified that investments in E&P is the appropriate answer and the only way to convert "potentials" into reality as did the US, and put an end to uncertainty and speculative discussions (Argentinians are very affect to discuss and argue, better than doing).

The Austral and San Jorge Golf Basins complete the country shale resources picture - Mendoza and North Basins were not part of the search-

Table 3- Comparison of TRR of Argentina - 1st y 2nd Report

Cuenca	Formación	Gas in Place	1er Informe				2do Informe	
			Factor de Éxito Comb.	Risked Gas in Place	Factor Recup.	RTR Gas (Tcf)	RTR Gas (Tcf)	Bill bls Oil
Neuquina	Los Molles		40%	478	35%	167	275	3,66
	Vaca Muerta		48%	687	35%	240	308	16,22
	Sub Total			1,165		407	583	19,9
San Jorge	Aguada Bandera		20%	250	20%	50	50,8	
	Pozo D- 129		24%	180	25%	45	34,8	0,5
	Sub Total			430		95	86	0,5
Austral- Magall.	L. Inoceramus		25%	429	20%	84	129	6,6
	Magnas Verdes		25%	351	25%	88	3	0,01
	Sub Total			780		172	132,2	6,6
Chaco- Paran.	San Alfredo		12%	667	15%	100		0
TOTAL						774	801	27

Fuente: Tablas A.1 y B.1 Informe DOE (no se evaluaron la C. Cuyana y del Noroeste)

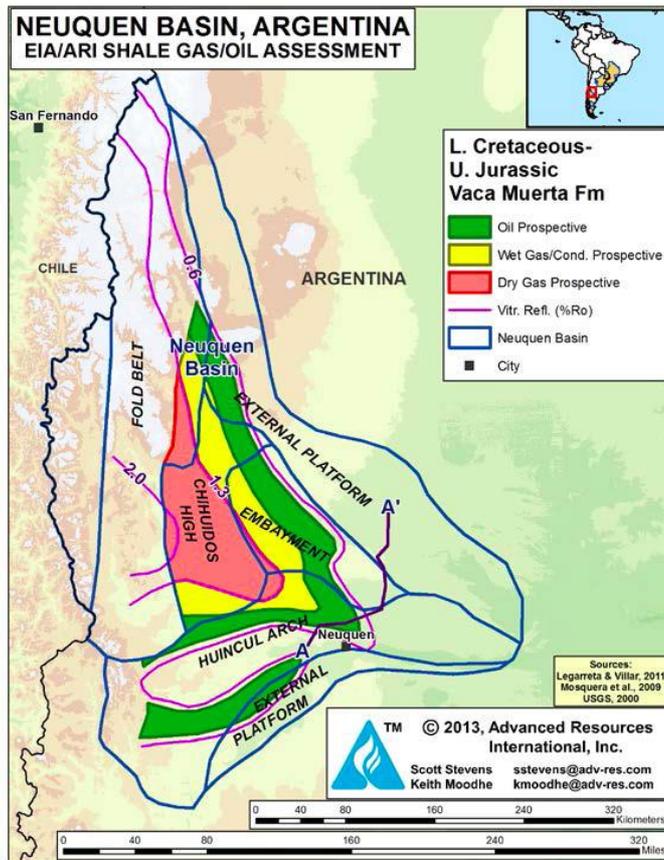
The TRR obtained in this Report uses Recovery Factors based on practical experience, the same that are used by specialists to estimate future production in any commercially field. After recent developments reveal that these formations are able to produce gas, crude oil, condensate and other gas liquids (LPG and C₅⁺), assuming adequate processing.

The criteria used to determine the possible existence of shale formations is Total Organic Content (TOC), which excludes any formation with TOC less than 2.

Thermal Maturity measures the exposure degree of a formation to high temperature and pressure to decompose organic materials into hydrocarbons. It utilizes the “Vitrinite Reflectance R₀” criteria as an indicator to define the Prospective Areas and predict the three possible hydrocarbons “windows”: (1) dry gas, (2) a mix of wet gas and condensate, or (3) crude oil.

Following these criteria, Figure 2 shows the oil prospective areas are located to the east and south, while dry gas is found to the west. Wet gas and condensate are located both among and between these zones.

Figure 2. Vaca Muerta Shale Gas and Shale Oil Prospective Areas



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