Development of a methodology for evaluating investments in infrastructure for the sustainable exploitation of shale energy in Argentina

by

Bruno R. Agosta

Civil Engineer, Pontifical Catholic University of Argentina, 2008

Submitted to the Department of Civil and Environment Engineering in partial fulfillment of the requirements for the degrees of

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Abstract

In 2011, a new word entered into the popular vocabulary of Argentina: Vaca Muerta (VM, literally: *Dead Cow*); almost like a discovery, it was announced that Argentina had large hydrocarbon resources that were trapped in underground shale and tight rocks. In reality, these resources were known by geologists from the beginning of the oil industry, but only became economically extractable in the 2000s, with the use of two old technologies developed in the US and already used on conventional fields: hydraulic fracturing and horizontal drilling. With this "discovery," the Argentine energy perspective changed radically: a sector that was declining became dynamic again and became a target for investment for a project that for many Argentines was still just a name.

By 2014, around three billion dollars has been invested in VM almost exclusively by the oil & gas sector, led by the national oil company (YPF), but there were very few analyses on how VM would affect other sectors, like the logistics and transportation system. By the intrinsic technical characteristics of these two essential technologies, the amount of inputs required in the wellheads is extremely high (especially in comparison with conventional exploitations), producing a strong demand for transportation and logistics services. This high volume of transportation services requires infrastructure capacity, meaning large long–term investments. Following this, a key question arises: who should pay for new capacity of public infrastructure that will be used by a few actors in a private business (oil and gas) that is profitable? Should it be the public sector through the use of tax-revenues or should it be the private sector that must pay with its own savings generated by using more efficient transport modes?

Seeking to answer these questions, this thesis developed and implemented a Simultaneous Economic-Financial Analysis Model (SEFAM) to evaluate the private and public incentives that will finally determine investment alternatives to achieve socially optimal solutions. The CLIOS Process, for studying complex sociotechnical systems, is used to study the relationships between the shale oil production system and the logistic and transportation system, with the institutional actors that govern them. The East-West VM supply corridor was selected as the research case of this thesis, in order to implement SEFAM and draw some general conclusions.

This research describes this interaction between shale energy production and its logistic and transportation requirements, along with the proposition of certain questions that advance a better understanding of the problem. SEFAM is then seen as an integrative tool that allows the decision-maker to have useful and relevant information for a prospective negotiation process between the public and private sectors, looking to ensure the implementation of the socially optimal alternative.

Thesis Supervisor: Joseph M. Sussman
Title: JR East Professor of Civil and Environmental Engineering and Engineering Systems

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"If we had to summarize in one sentence the mission of engineers and technical workers in this country [Argentina] today, we could say that it is to be at the service of national development. So, that they should stimulate the productive forces, widening at the same time the social and economic foundations of our democracy. It is essential that our engineers and technicians take into account the national reality and the need to transform it into a reality of progress and welfare. This means that they must act in technical-economic function and should deepen and enhance its scientific and technological capacity, aiming to solve the most urgent problems of our economy."

Arturo Frondizi
32nd President of Argentina (1958-1962)
Centro Argentino de Ingenieros, May 23, 1958

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Biographical note

Bruno R. Agosta is a Civil Engineer from the Catholic University of Argentina (UCA). Upon his graduation in 2008, he received the *Medalla de oro*, the university's highest award for graduating students, and was the valedictorian with the highest GDP along graduating civil engineers by the Civil Engineers Professional Council of Argentina (CPIC). Before joining MIT, Bruno led logistics and transportation infrastructure projects in Europe and Latin America, and since 2011 has been part of the engineering company AC&A. In 2013, Bruno was awarded the Fulbright-BEC.AR Fellowship, the Organization of American State (OAS) Scholarship representing Argentina and the International Road Federation Fellowship, to study for a master's degree in the United States. Bruno grew up in Buenos Aires, Argentina where his family still resides.

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Glossary of terms and acronyms

AADT	Annual Average Daily Traffic
ASoE	Argentine Secretary of Energy
BCA	Benefit Cost Analysis
BTU	British Thermal Unit
CLIOS Process	A methodology for studying for studying complex sociotechnical systems described in Sussman (2014).
CLIOS system	Complex, large-scale, interconnected, open, sociotechnical system (Sussman 2014)
DNV	Dirección Nacional de Vialidad of Argentina
EIA	United States Energy Information Administration
ENARSA	State owned energy company of Argentina. The acronym refers to *ENergía ARgentina Sociedad Anónima*
ESAL	Equivalent Single Axle Load
GyP	Gas y Petróleo de Neuquén. Provincial state-owned oil company
HCM	Highway Capacity Manual
IOC	International Oil Company
JV	Joint Venture
LM	Los Molles formation
LNG	Liquefied Natural Gas
MIT	Massachusetts Institute of Technology
NOC	National Oil Company
O&G	Oil and Gas
OPEC	Organization of the Petroleum Exporting Countries
Open Access	Open Access involves physical infrastructure (i.e. railways) being made available to clients other than the owners, for a toll
PPP	Public-Private Partnership
RN22	Argentine National Highway No 22
RP7	Neuquén Provincial Highway No 7
SEFAM	Simultaneous Economic-Financial Analysis Model
Tcf	Trillion cubic feet
tonne	Metric tonne: unit of mass equivalent to 1,000 kilograms
US	United States of America
US DoE	United States Department of Energy
VM	Vaca Muerta formation
YPF	National oil company of Argentina. The acronym refers to *Yacimientos Petrolíferos Fiscales*

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Chapter 1. INTRODUCTION AND MOTIVATION

In November 2011, a series of public announcements about the “discovery”[1] of unconventional oil in a formation called "Vaca Muerta"[2] (VM) in Patagonia (NY Times 2011), together with a publication of a US Energy Information Agency (EIA) report indicating that Argentina had the third largest shale gas reserves in the world, after the United States and China (EIA 2011), generated a shock in expectations in the Argentine energy sector. In a very short time, the oil-industry perspective radically changed to such an extent that a resource that less than three years before was not even generally mentioned, was now seen as a potential "game-changer" for the country.

These changes generated a climate of uncertainty about what this “unknown” resource was and what would be the impact on the real economy. The author found himself very intrigued by the potential of these "new" resources that overnight became the great promise of national development, and in particular the implications on transportation and logistics infrastructure development.

After the unification of the country and the consolidation of a federal government in the second half of the nineteenth century, the Argentine economy started a period of extraordinary growth and prosperity, with an economic structure based on the export of agricultural commodities. This period positioned the country as one of the 8 major economies in the world in 1910 (in 2014 it was 24). In this context, Argentina's oil industry was born in late 1907 with the first oil discovery in Comodoro Rivadavia, Patagonia, which was then followed by a series of investments, domestic and foreign (Gadano 2006).

The economic history of Argentina in the twentieth century was marked by political instability, generating a real deterioration of the economy and a partial change in the production structure, incorporating industrial and services sectors, based in major cities. The agricultural sector remained one of the economic pillars of Argentina, but decreased its relative weight. The oil industry followed the general trend, having periods of growth and decline, but always conditioned by the limited amount of oil and gas reserves that were available. In particular, there was a relatively good development of the sector in the late 1990s, when a predominantly private sector

[1] Even if the existence of these resources was included in the geological literature since 1892 (AAPG 2012), for the general public these announcements were seen as "new discoveries" (La Nación 2011).
[2] The name of Vaca Muerta Formation was introduced to the geological literature in 1931 by an American geologist Charles E. Weaver, that was exploring the area for the California Stardard Oil (now Chevron) and identified the formation on the side of the mountain “Sierra de la Vaca Muerta” (ShaleArgentina.org)

investment generated not only self-sufficiency of the country but exportable surpluses. These achievements were blurred for various reasons at the beginning of this century. In any case, Argentina was always considered as a country with oil, but not as an "oil country.[3]"

Within this context, there was a general feeling that the unconventional oil and gas in Patagonia could be the key for development, allowing the country to return the path of growth and prosperity with social inclusion and the regional and global importance that it once had a century ago. The challenge for the social inclusion is to avoid that the "extractive economy" only benefits part of the population, leaving apart the most vulnerable sectors (The Economist 2012b).

However by 2014, the author realized that beyond the oil industry's own investments, there was no research studying the real challenges that this project would bring to the Argentine society. In particular, there was a need to understand how to assess the impact on existing transportation and logistics infrastructure and to investigate the planning and financing process of the new investments that this development would require. In this regard, studies made in different oil-production states of the US from 2005 were a strong inspiration to identify the real problems that the region and the country would eventually face, and the need to address these challenges in the early stages of the development.

This thesis will try to help answer questions focused on the understanding of the potential of these resources, and then to promote the debate about how transportation and logistics infrastructure should be built, not only to support this development, but also to induce it by lowering transportation costs, gaining greater efficiency.

There is almost general consensus that the world energy consumption will grow in the coming decades at an increasing pace. In 2011, the EIA estimated that the overall energy consumption of the world would increase by 53% between 2008 and 2035 with half of the increase in demand attributed to China and India (Figure 1-1). In this context, fossil fuels continue to be fundamental and probably will remain so in the medium term. In fact the same EIA report estimates that fossil fuels share by 2035 will be 80% of total world energy supply, when currently it is 86% (Figure 1-2).

[3] The phrase: *"Argentina is not an oil country; it is a country with oil"* was apparently said by Gustavo Petracchi, former Energy Secretary of Argentina and head of Gas del Estado (HBS Case 9-713-029 2013)

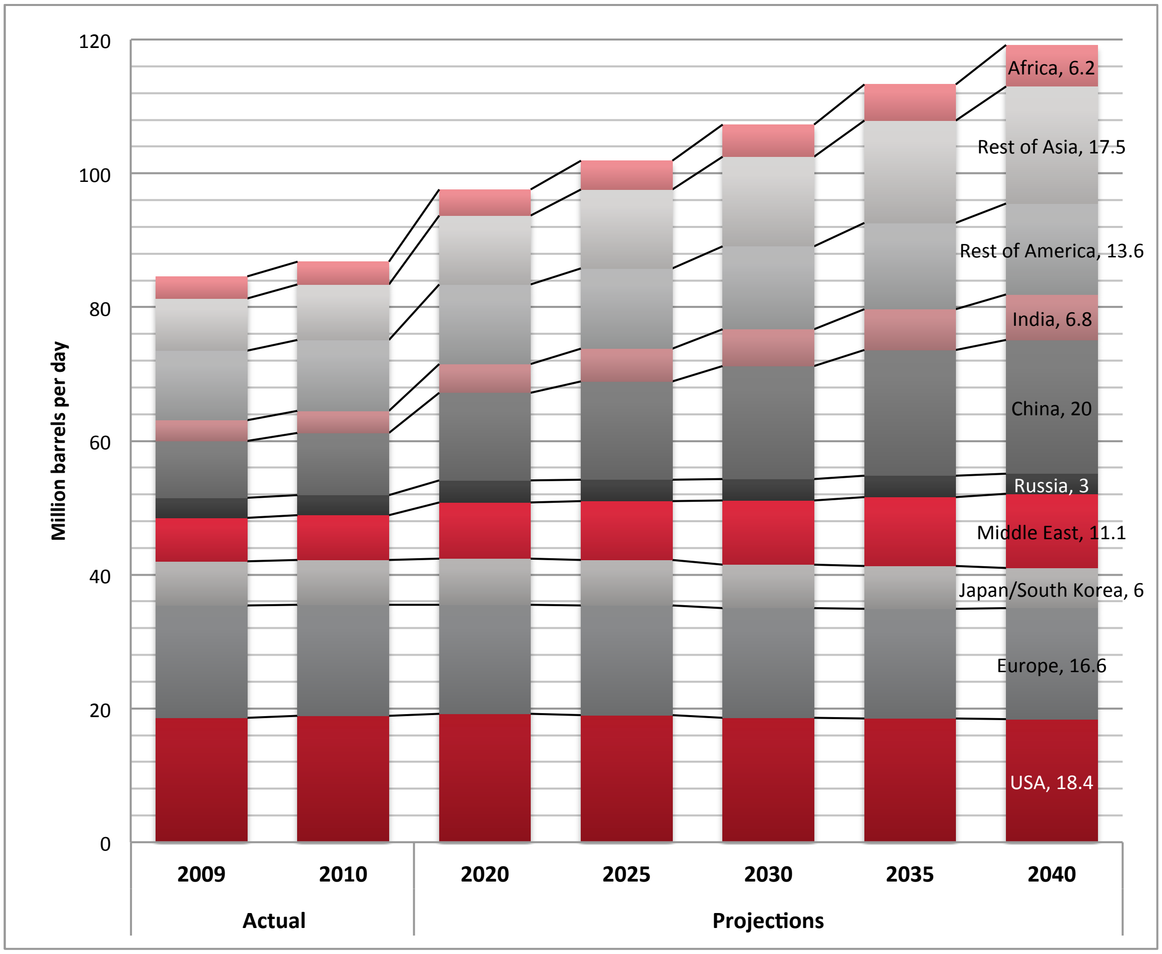

Figure 1-1 World petroleum and other liquid fuel consumption by region in million barrels per day (EIA 2014)

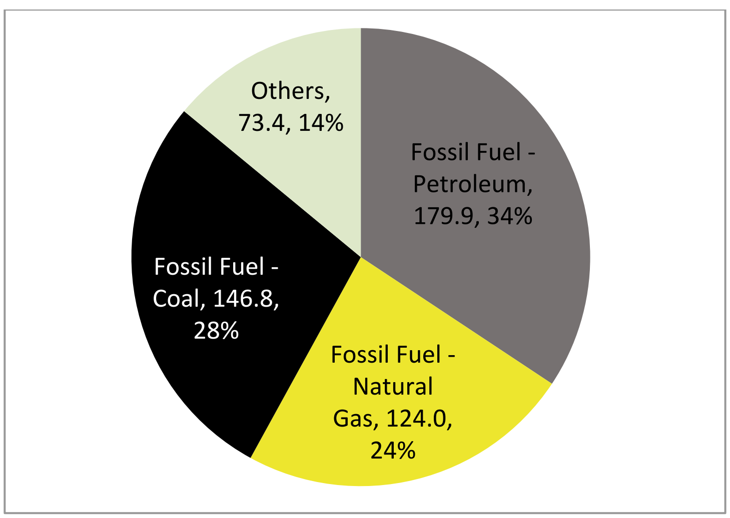

Figure 1-2 Total world's energy consumption by source in 2012 in quadrillion Btu (EIA International Energy Statistics website[4])

[4] US Energy Information Administration website retrieved on March 6th, 2015: http://www.eia.gov/countries/data.cfm.

Within this context, the increasing supplies of natural gas extracted from shale (called "unconventional" because of the method of extraction) are in line with the projected growth in natural gas use worldwide. In terms of crude oil, the unconventional are expected to be 12% of world total production by 2035 (Figure 1-3)

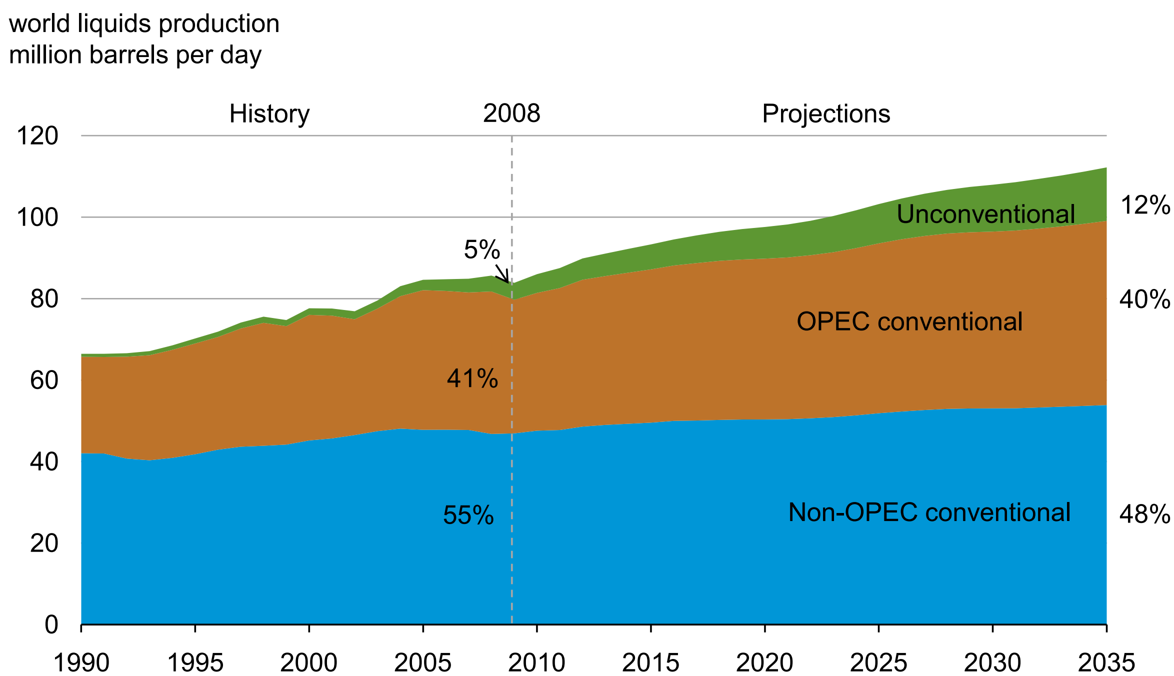

Figure 1-3 World liquids fuel production in million barrels per day 1990-2035 (EIA 2011b)

But there are still some big issues to be addressed, especially greenhouse gas emissions reduction. Renewables and natural gas are growing fast, but coal will probably still fuel the largest share of the world's electricity in 2035 (EIA 2011), generating the largest share of carbon dioxide emissions. In this regard, gas operations with rigorous control systems to avoid methane leaks, can be environmentally very efficient for electricity generation in comparison with the burning of coal.

Given that the demand for energy is high and will continue to grow in the future, driven by the development of new emerging economies, and even if energy sources will diversify, at least in the medium term oil and especially gas will continue to be essential. Therefore unconventional resources will be important in the global energy sector, but also can be "game-changers" in regional terms, like in the case of Argentina. This "game-changer" effect, as will be discussed in the following chapters, will be driven in part by oil, but especially by natural gas through the possibility of having "cheap" energy in large amounts available for other sectors, such as for example energy-intensive industries like petrochemicals and aluminum. This multiplier effect goes beyond the energy sector, as is being seen in the last years in the US, and may profoundly impact the industrial structure of a region or a country. As will be presented in Chapter 2, inbound logistics for natural gas and crude oil are the same since, since both resources require the same extraction technologies. In the case of outbound logistics, in general natural gas is transported by pipelines and crude oil is transported by railcars, pipeline or even trucks.

A parallel point that is worth mentioning at this point is the current debate in some US states and especially in Europe about the environmental risks associated with the technologies required to extract shale oil and shale gas, specifically hydraulic fracturing, commonly called "fracking." At this point, under the scope of this thesis, the author propose a hypothesis in order to allow this thesis to focus on the specific object of this research: infrastructure planning. The hypothesis is to assume that, knowing that environmental risks exist, there are good construction and operating practices implemented in the US and abroad that allow the safe exploitation of these types of resources. This hypothesis is based on the findings of two reports: “The Future of Natural Gas: An Interdisciplinary MIT Study” from the MIT Energy Initiative and the “Second Ninety Day Report” from the Shale Gas Production Subcommittee of the Secretary of Energy Advisory Board of November 2011. These reports state:

MIT Energy Initiative Report (MIT 2011): “The environmental impacts of shale development are challenging but manageable. Shale development requires large-scale fracturing of the shale formation to induce economic production rates. There has been concern that these fractures can also penetrate shallow freshwater zones and contaminate them with fracturing fluid, but there is no evidence that this is occurring. There is, however, evidence of natural gas migration into freshwater zones in some areas, most likely as a result of substandard well completion practices by a few operators. There are additional environmental challenges in the area of water management, particularly the effective disposal of fracture fluids. Concerns with this issue are particularly acute in regions that have not previously experienced large-scale oil and natural gas development, especially those overlying the massive Marcellus shale, and do not have a well-developed subsurface water disposal infrastructure. It is essential that both large and small companies follow industry best practices; that water supply and disposal are coordinated on a regional basis and that improved methods are developed for recycling of returned fracture fluids.”

US DoE Report (US DoE 2011): “On August 18, 2011 the Subcommittee presented its initial Ninety-Day Report1 including twenty recommendations that the Subcommittee believes, if implemented, would assure that the nation’s considerable shale gas resources are being developed responsibly, in a way that protects human health and the environment and is most beneficial to the nation.”

Thus, this thesis will focus on how the decisions about the public infrastructure required for the shale energy development should be made. How should the interaction between public and private actors in the development of this infrastructure be managed? What should the planning, financing and regulation structure be? The following Section 1.1 provides further background on the purpose of this thesis. Then, Section 1.2 specifies the more precise questions that were the basis for this thesis and explains the methodology used to address them. In Section 1.3, the actual research case that is going to be used as an example will be shown and finally this opening chapter is concluded in Section 1.5.

1.1. THESIS PURPOSE

The aim of this thesis is to understand the process of changes in the Argentine energy sector due to the shale energy developments, and its particular interaction with the transportation and logistics systems. With the analysis of what happened in the US shale boom and identifying the differences and similarities with the Argentine case, this thesis will seek to define the overall context and provide a new methodology for analyzing how infrastructure decisions should be made in this context. For an example of that methodology, a research case related to the transportation infrastructure in Argentina will be used.

The location of VM, away from large urban centers, coupled with the high requirements of inputs that are needed to be transported into the area (one of the main characteristics of the extraction technique) makes the logistics and transport components key elements of the analysis of the shale energy industry. At the same time and because of the historic economic development of the country, the oil industry and the region, the logistics system and transport infrastructure in this region was not designed for the level of demand that the exploitation of VM requires. Immediate problems like lack of network connectivity and high saturation of the existing infrastructure are problems that should be solved in the short term in order to achieve an efficient operation. In fact a report by the Belfer Center of the Harvard Kennedy School (Mares 2013) states: "Investment in logistics and infrastructure is necessary to support it [VM exploitation], the lack of which has made the cost of a shale well in Argentina more than double that in the United States ($7-8 million compared to $3 million)."

The situation is a major challenge for the transportation and logistics industry, which will affect not only the oil industry but will generate changes in regional economies. Therefore it is necessary to assess synergies and evaluate transportation alternatives to make strategic decisions at early stages of the project. However, this investment planning requires a different perspective than regular public infrastructure project evaluation, since in this case there is a strong interaction between public and private actors to be considered in the decision. The absence of a global view in the planning process may generate errors that could affect the development of Argentina in the coming decades.

It is noteworthy that the use of technologies needed to develop such non-conventional oil and gas became widespread in recent years, so the knowledge regarding methodologies of infrastructure planning, has not been thoroughly investigated worldwide; this is what makes this research interesting and innovative. To advance the detailed analysis of the problem, in Section 1.2 three clusters of interrelated questions are introduced.

1.2. THESIS QUESTIONS AND APPROACHES

In the process of answering the general question stated—how should the logistics and transportation infrastructure related to shale developments, in particular VM, be planned and funded—, three more detailed question clusters are posed. This set of three question clusters created from the point of view of a decision-maker, are ultimately the input to conceptualize the requirements of the methodology developed in Chapter 4. This methodology will be based on the Benefit-Cost Analysis (BCA) technique applied to a specific complex-decision scenario where there are private actors with strong decision-power and a complex public and institutional framework.

1.2.1. QUESTION CLUSTER 1: TRANSPORTATION AND LOGISTICS REQUIREMENTS

The infrastructure investments are long-term and expensive decisions for society. What is driving the demand for new infrastructure capacity for shale energy developments in Argentina? What are the bundles of strategic alternatives for providing this transportation capacity? Which institutional actors have influence over the implementation of these alternatives?

This cluster of questions is answered at two levels: the first focusing on the shale energy development system and the second focusing on the logistics and transportation system. The first level analyzes shale developments identifying general and local characteristics, evaluating the development over time and particularly identifying the key drivers of transportation demand. The second level focuses on identifying current and future transportation alternatives. This response seeks to identify the general context of the shale industry and the transportation system in Argentina, in order to introduce in Question 2 the analysis of the interrelationships among actors.

1.2.2. *QUESTION CLUSTER 2: ANALYSIS OF BUNDLES OF STRATEGIC ALTERNATIVES IN A CLIOS SYSTEM*

How can we analyze these bundles of strategic alternatives taking into account the particular interests of each of the actors? How should we design the infrastructure? How can we generate useful information for the discussions on infrastructure finance that allows the actors to work toward an optimal decision for the country? How does uncertainty affect the strategies of the actors?

The response to this question will look at the interaction between the actors involved. To respond to Questions 1 and 2, concepts from the CLIOS Process will be used to organize the work. The CLIOS Process is an approach to studying complex, large-scale, interconnected, open, sociotechnical (CLIOS) Systems. CLIOS systems are a class of complex sociotechnical systems with "nested complexity" (Sussman 2014). Besides being a tool for understanding the system, the CLIOS Process can be used for "intervening in" and changing the system to improve outcomes or performance. These alternatives are intended to enhance the performance of the CLIOS System are called "bundles of strategic alternatives" (Sussman 2014).

The CLIOS Process is organized into three stages:

1. Representation of the CLIOS System structure and behavior,

2. Design, Evaluation and Selection of CLIOS System bundles of strategic alternatives, and

3. Implementation of the selected bundles of strategic alternatives.

This thesis will use the first stage that is descriptive as an "organizing mechanism for mapping out the system's underlying structure and behavior–a precursor to identifying strategic alternatives for improving the system's performance" (Sussman 2014). This representation will be used as the definitions of the systems and the interaction between the actors that will be the background for the development of the methodology of analysis to answer the Question cluster 3.

1.2.3. *QUESTION CLUSTER 3: PUBLIC AND PRIVATE PARTICIPATION*

If the private sector should lead the role of financing infrastructure development, what considerations of planning and regulation should be addressed? What should the framework be to ensure fair competition for the use of the infrastructure to guarantee the pursuit of

efficiency for all current or future stakeholders? What should the design of the institutional architecture be?

The response to this question will be the product of the methodology described in Chapter 4. The objective will be to develop a framework that contains the interaction between the different systems and the institutional sphere that look into the decision on how the logistics and transportation infrastructure required for the shale energy development in Argentina should be planned, built and operated. In particular, this methodology will consider different perspectives, starting from a global analysis of economic efficiency to move towards a financial assessment from the point of view of private investment. This dual vision seeks to identify incentives and linkages between all the actors, to finally define the range of possible alternatives.

1.3. SIMULTANEOUS ECONOMIC-FINANCIAL ANALYSIS

The methodology that will be presented in Chapter 4 is the Simultaneous Economic-Financial Analysis Model (SEFAM), which allows us to analyze the system from different perspectives, including those of each major actor. This methodology leads to the definition and generation of the useful information required in a prospective negotiation between the actors, in the attempt to reach the optimal solution for the society.

As will be described in the Section 4.5, the existing literature is mainly focused on two perspectives: on one side, some authors analyze the methods of Benefit-Cost Analysis (Kurowski et al. 2011 and Zerbe 1994) and on the other are those who study the Public Private Partnerships or other instruments of private sector participation in infrastructure investments (Delmon 2009, Merna et al. 2002 and Grigg 2010). In this thesis, ideas and quotes from these authors are presented to illustrate the thinking on these topics. The author believes that the value added by SEFAM is the consolidation in one tool of known methods, which provides the decision maker with useful information for a negotiation process that may lead to the social optimum, helping to understand and solve a concrete problem from a dual perspective.

The use of SEFAM allows us to generate new alternatives that would not exist if the government and the private sector did both analyses individually. As will be seen in the application of SEFAM to the research case, the creation of possible new solutions that align the incentives of the private sector toward the socially optimum alternative is a value added by this model. Since the solution will require a negotiation process, the structure of SEFAM as a model that makes this simultaneous analysis together with a fiscal assessment, is a novel idea especially for the use of decision makers in the private sector dealing with expensive infrastructure decisions.

1.4. RESEARCH CASE: CORRIDOR TO SUPPLY VACA MUERTA (VM)

Looking to illustrate the methodology developed in Chapter 4 (SEFAM), within the scope of this thesis, the author chose to use as a research case the corridor between Bahía Blanca and Neuquén that includes a railway line and a main national highway as a proof of concept.

As will be explained in Chapter 2, VM formation is included in the so-called "Neuquén Basin" in Patagonia. Its depth, its geological characteristics and the results of the first stages of exploration and production are very promising, positioning this formation as one of the best current shale plays outside the US (McGowen 2013).

The main infrastructure that serves this area is the national and provincial road system and the railway branch Bahía Blanca-Zapala under the private concession of Ferrosur Roca. This railway has an extensive network including important port connections in Buenos Aires and Bahia Blanca.

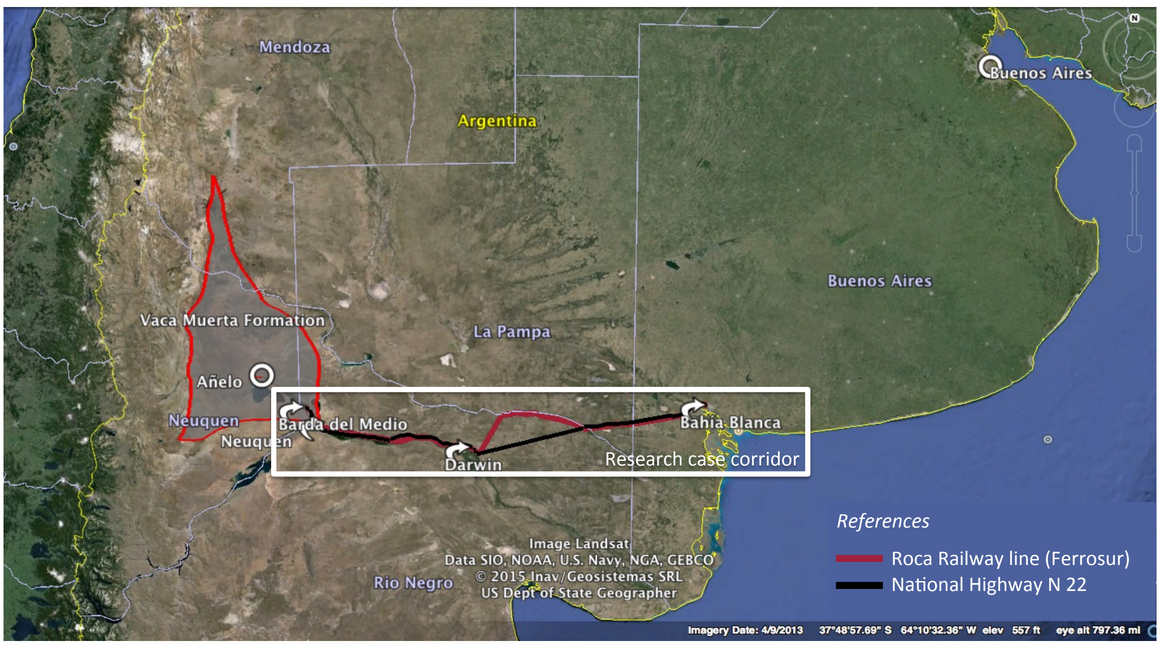

Figure 1-4 Research case corridor (Adapted from Google Earth)

This corridor was chosen as research case because it exemplifies the competition between modes. In particular the railway infrastructure segment is important because:

- It is a key infrastructure in terms of its potential transportation capacity
- It is crucial to promoting the sustainable exploitation of shale resources of VM

- For its development, a coordination of different actors is required: national government, rail operator, regulator, operators of oil fields, unions, etc.
- To achieve an efficient operation, this infrastructure requires a high level of capital investment, requiring a considerable planning effort.

The application of this research case is an academic exercise to demonstrate the use of SEFAM, which can then be applied in other infrastructure planning cases or even could serve as a conceptual framework for analyzing a similar problem in the development of other natural resources (e.g. mining). This implementation was developed with public information from secondary sources, so the results are suitable for the first overview analysis. We will call this corridor the "East-West VM supply corridor", for further reference.

Section 1.5 will summarize the structure of the following chapters of this thesis.

1.5. CLOSING

This chapter started with the discussion about the increasing global energy consumption and the perspectives of the shale energy as a potential driver for the development of Argentina. Those general ideas were then related to the need for large investments in infrastructure in a context of public-private decisions that will be detailed in Chapter 4. Finally we introduced the motivations for writing this thesis, developing the associated methodology and using the VM supply corridor research case to exemplify its application. This methodology will look to this problem from different perspectives, seeking to define how to implement the socially optimum transportation alternative.

In a logical order, the following Chapter 2 will focus on the definition of the systems involved and their characteristics. Chapter 3 will analyze the interactions between the different actors through the implementation of Stage 1 of the CLIOS Process and Chapter 4 use the outcome from the first two chapters to present SEFAM and its application in the research case of VM. Finally Chapter 5 summarizes the main conclusions and recommendations and enumerates possible further studies.

Then we move into the detailed definition of the systems in the next chapter.

Chapter 2. UNDERSTANDING SHALE ENERGY, ITS INFRASTRUCTURE REQUIREMENTS AND CHARACTERISTICS

This chapter describes the characteristics of the development of shale energy in general, to understand their structure and especially to give a theoretical framework to determine why the infrastructure capacity is crucial. Within this chapter a benchmark of the US shale boom and the Vaca Muerta case will be developed, looking at similarities and differences, given that Argentina is already the largest producer of shale energy outside the United States and Canada (YPF Press 2015).

2.1. SHALE ENERGY

2.1.1. INTRODUCTION TO SHALE ENERGY

For decades geologists have known that inside the "source rock" vast amounts of hydrocarbons were trapped. Because of the very low permeability and porosity of the rock, these hydrocarbons were unable to flow to areas of lower pressure (reservoirs) in a process called "migration" (Figure 2-1) and consequently could not be extracted in the conventional way (Figure 2-2).

This light crude oil with low sulfur content and gas found in low-permeability shale and tight formations are called shale oil/gas and tight oil/gas. Even shale oil reservoirs are rich with clay and fissile, and tight oil formations are made of siltstone or mudstone without a lot of clay. However, the resemblance on data logs between the two made the term "shale" the common name for both types of oil. However, this kind of oil should not be confused with "oil shale", a product with different chemical composition that requires different extraction and refining techniques (Maugeri 2013).

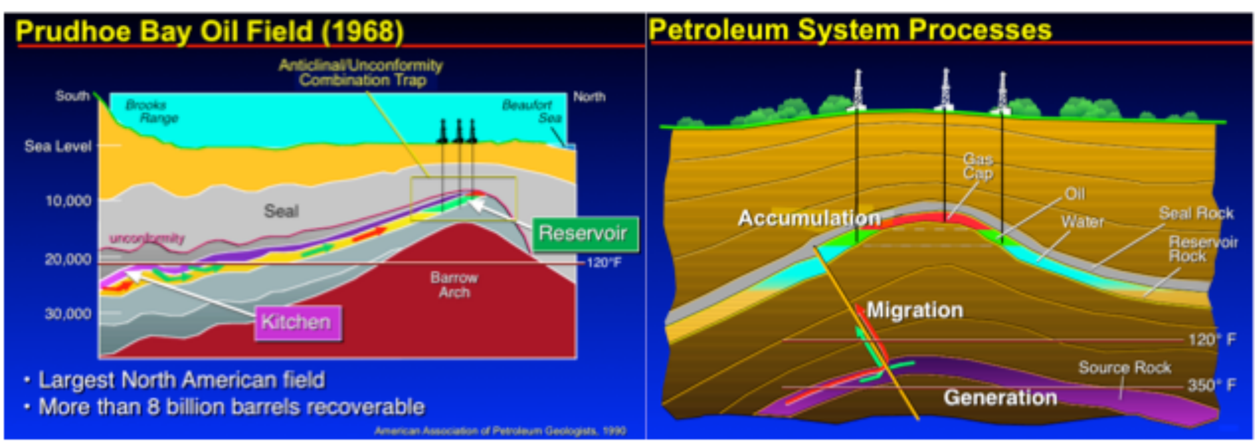

Figure 2-1 Basics of petroleum system processes (AAPG 1990)

The shale resources are included in the group of "unconventional" since they are produced or extracted using techniques other than the conventional method. The attention to these resources has increased in the last decades driven by the known scarcity of conventional oil reserves. Inside the "unconventional" group, there are others kinds of crude oil such as the oil sands (bitumen), extra-heavy oils and oil shale (kerogen) (Belouga 2012).

In particular, the tar sands (or oil sands) in Canada are another example of massive development of unconventional oil, but it is important to mention that the physical-chemical characteristics of the oil sands and the shale oil are very different, as are their extracting technologies. In the case of oil sands in Canada, the operation is very similar to a mining process and requires a lot of energy to extract, process and transport the oil. In the case of shale oil, the product is lighter with a better quality, and it is extracted through perforations as is the conventional oil, even if the processes involved different technologies that require more input materials and consequently more transport services.

In Figure 2-2**,** a simplification of the difference between conventional and unconventional reservoir types is shown.

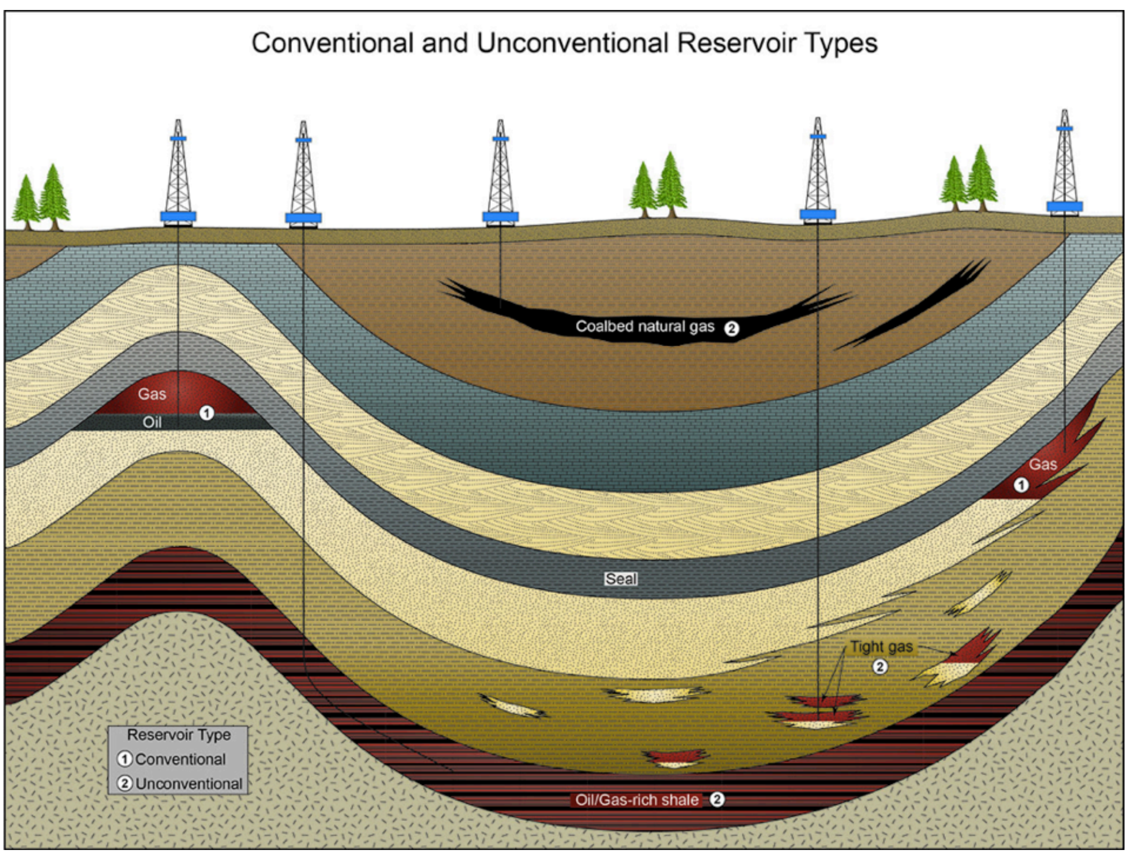

Figure 2-2 Conventional and Unconventional Reservoir Types (WSGS 2015)

Two technologies are crucial for the exploitation of these resources: hydraulic fracturing combined with horizontal drilling.

Hydraulic fracturing is a technique that was first introduced into commercial practice in 1947 for well stimulation[5] on conventional reservoirs in which the rock is fractured by a hydraulically pressurized mix of water, sand and chemicals. The water fractures the rock through high-pressure. The sand (or *frac-sand*) is used as a propping agent in order to assure that the fissure created remains open after the external hydraulic pressure disappears. This frac-sand could be in some cases replaced by man-made ceramic materials. Finally chemicals have different functions during the process, as we will see in the following chapters, and their composition is a topic of heated discussion, especially in some states of the US who are concerned about groundwater contamination. So, it is important to make clear that hydraulic fracturing did not begin in the twenty-first century with the US shale boom, but comes from developments from over 50 years and diverse implementations.

Horizontal drilling is a technology that has been widely practiced since the 1980s to extract conventional oil, allowing a directional drilling in different angles, even horizontal. This directional drilling allows the producer to:

- Increase the length of the exposure section through the reservoir, allowing more surface to be in contact with the reservoir rock
- Drill into parts of the reservoir where vertical drilling would be impossible, as for example under a occupied surface (i.e. under Dallas/Fort Worth Airport shown in Figure 2-3) or a difficult-to-drill covering rock
- Combine different wellheads into one pad, reducing the surface disturbance
- Reduce the pressure of an uncontrolled well in an emergency action.

In conclusion, neither the horizontal drilling nor hydraulic fracturing are new technologies, but their application in recent years were at an unprecedented pace and scale, becoming key drivers for the development of shale resources in an economically viable manner. This combination has allowed oil producers to economically extract oil from these sources in the US, raising the production from almost no production up to 1.5 million barrels per day of shale oil in 2012 (Maugeri 2013).

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[5] Oil well stimulation is the general term describing a variety of operations performed on a well to improve its productivity (http://www.oilprimer.com/oil-well-stimulation.html)

Figure 2-3 Horizontal drilling allows the exploitation of the Barnett reservoir below the Dallas/Fort Worth (DFW) Airport (Star Telegram 2015)

As was introduced in the first chapter, the author considers that it is important to highlight the controversy that exists in terms of the use of these two technologies, specially hydraulic fracturing ("fracking"). Clearly, this is a complex debate with both technical objective and subjective elements, like any discussion of this type. As was previously mentioned, since this study is focused in infrastructure developments and not in analyzing the environmental effects of the technologies involved in the extraction, the author proposed in Chapter 1 to advance a hypothesis in the context of this thesis: to assume that, knowing that environmental risks exist, there exists good construction and operating practices implemented in the US and abroad that allow the safe exploitation of these types of resources. This does not mean that always this good practices are applied or even that it should not be extremely necessary to have a set of clear, precise and transparent regulations, but this hypothesis just states that these good practices are materially possible and can mitigate the environmental risks associated with the shale exploitations. This hypothesis is based on the findings of two reports: "The Future of Natural Gas: An Interdisciplinary MIT Study" from the MIT Energy Initiative (MIT 2011) and the "Second Ninety Day Report" from the Shale Gas Production Subcommittee of the Secretary of Energy Advisory Board of November 2011 (US DoE 2011), previously quoted in Chapter 1.

Resuming the explanation of the two essential technologies (hydraulic fracturing and horizontal drilling), with the objective of providing the reader a scientific back-ground of why these two methods combined were the key for the development of the shale boom in the US, the author will use the example provided by Dr. Robert Kleinberg in a presentation organized in November 2014 by the MIT Energy Club (Kleinberg 2014):

The objective of the exploitation is to get the oil and gas flowing into the pipes of the wells. The flow of fluids in an oil well follows Darcy's Law:

$$Q = A\frac{k}{\mu}\nabla P$$

where Q *= fluid flow [cm³/s]*

A *= contact area [cm²]*

∇P *= pressure gradient [atm/cm]*

μ *= viscosity [cP] pressure gradient [atm/cm]. In natural gas,* μ*=0.01 cp (100°C)*

and k *= permeability to fluid flow [D]*

Since the permeability (k) of a conventional good gas reservoir is about 10^{-3}*D and the permeability of a shale gas formation is about* 10^{-7}*D, the only possibility to keep the same flow Q with the same viscosity and pressure gradient is by expanding the reservoir contact area (A) by a factor of* $\mathbf{10^4}$*!*

So, if the conventional reservoir is being exploited by a vertical 20 cm borehole in a 30 m thick reservoir providing a reservoir contact area of 20 m^2*, the analogous required reservoir contact area for the shale case would be: 200,000* m^2 *in order to produce the same flow (Q). This huge increment in the contact area is achieved by a dual action: increasing the pore dimension (fracturing of the rock) and increasing the length of the perforation in contact with the reservoir (the horizontal drilling), as shown in* Figure 2-4.

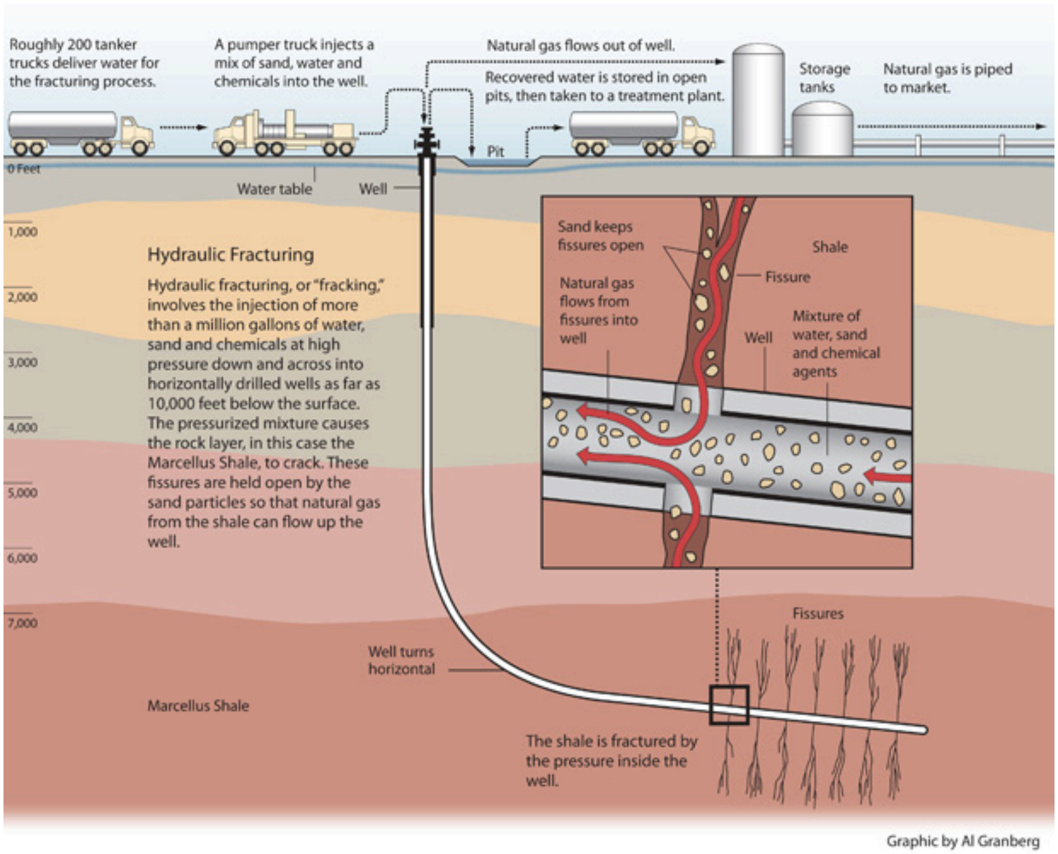


Figure 2-4 Horizontal drilling + hydraulic fracturing schematic well (Council of Foreign Relations 2015)

During this work, the compilation of shale oil and shale gas will be referred to as shale recourses. Both elements have similar geological formation and extraction techniques. However they have significant differences in economic terms since both products have very different markets, because of the impossibility of massively storing and transporting the natural gas. This "natural" restriction creates very different price behavior and socio-economic impacts between the two products: natural gas has a more local/regional impact than crude oil. The differences between products are addressed in the following chapters; for now the author will concentrate on the description of the technical aspects of both resources.

As was introduced before, since the early 2000s, the combination of horizontal drilling and hydraulic fracturing have allowed oil companies to put into production formations in different parts of the United States with different levels of production (Figure 2-5). The most important are:

- Marcellus shale (Pennsylvania, New York, and Ohio)
- Barnett, Permian Basin, and Eagle Ford shales (Texas)
- Haynesville (Louisiana)
- Fayetteville (Arkansas)

- Bakken (North Dakota)

In particular Bakken has remade the energy map in the United States incorporating over one million barrels per day of crude oil production (Council of Foreign Relations 2015), allowing the country to reach more than 9 million barrels per day in production of oil in 2014 (EIA 2015), becoming a top global producer and close to reaching the historic record of 10.04 million barrels a day reached in November 1970.

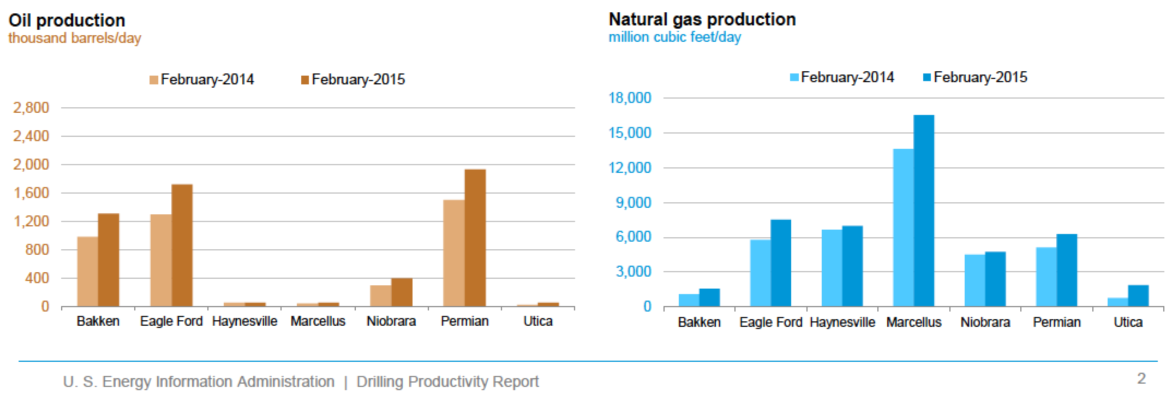


Figure 2-5 Oil and Gas production per shale formation in the US (EIA Drilling Productivity Report Feb 2015)

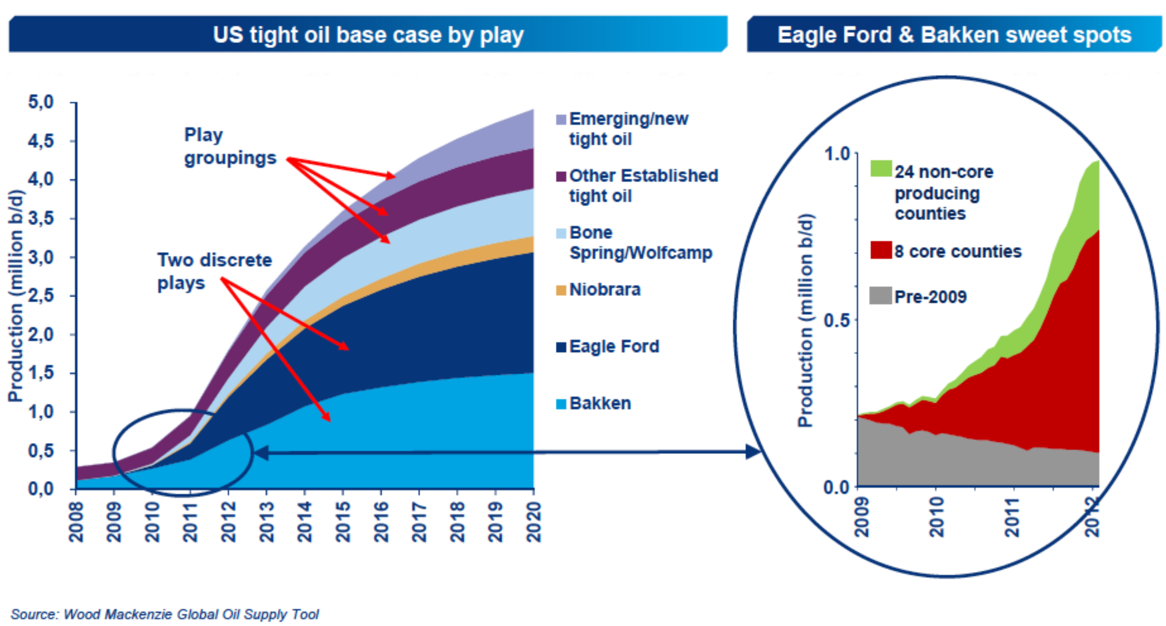


Figure 2-6 US shale oil by play projection (Wood Mackenzie 2014)

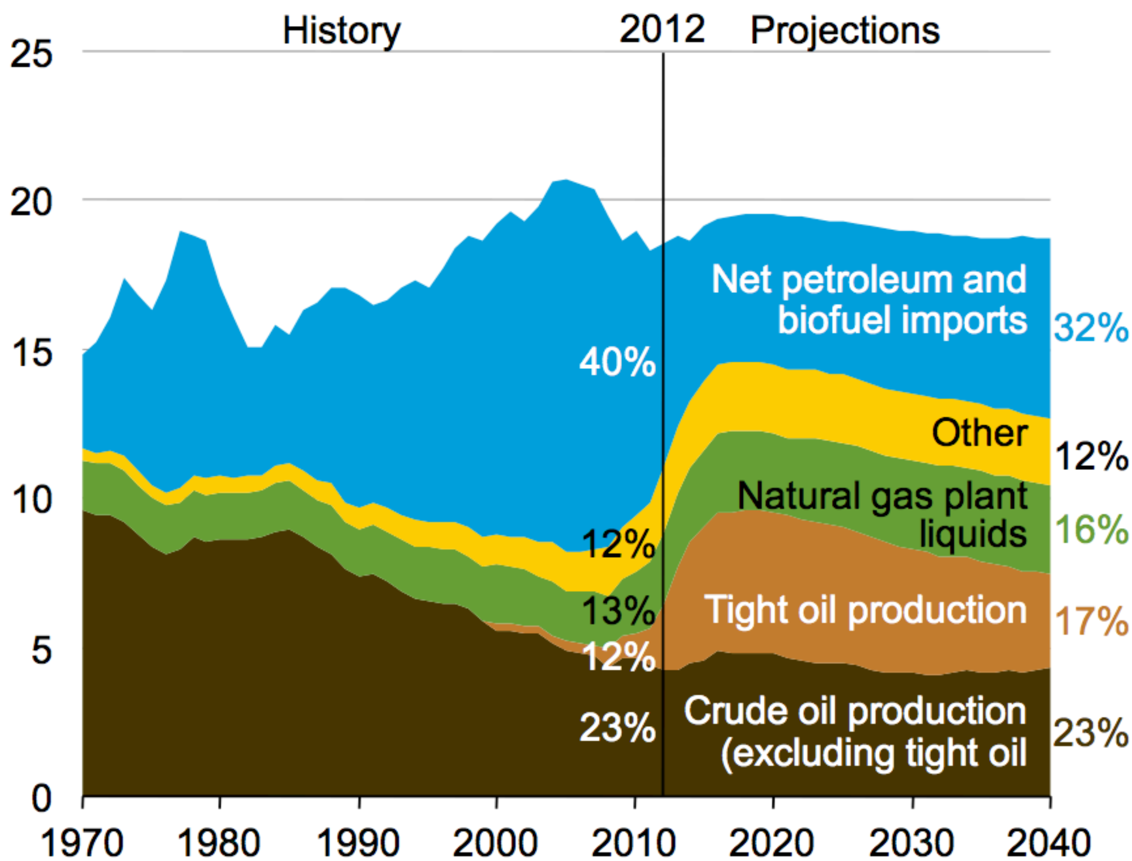


Figure 2-7 US petroleum and other liquids fuel supply by source 1970-2040 in million barrels per day (EIA 2014b)

Apart from the low permeability and porosity of the rocks, the other key technical characteristic of the shale wells is the rapid decrease in production rates. According to research developed by Maugeri (2013), from the initial production achieved during the first 30 days, production drops generally to 40-50% by the end of the first year (compared to 80% for conventional oil) and further to 30-40% by the end of the second year (conventional: 70%), according to results in the main 3 plays of the US (Bakken, Eagle Ford and Permian). Finally after 5-6 years, the production rate is approximately 20% of the initial production (conventional: 30%). A graphic showing the difference in production curves between conventional and tight oil is included in the Appendix of this thesis. The particular values of these rates depends on the geology of the formation and the technologies utilized by the operators, and is evolving over time (Figure 2-8), even if the pattern is maintained as a distinct intrinsic characteristic of this type of exploitation.

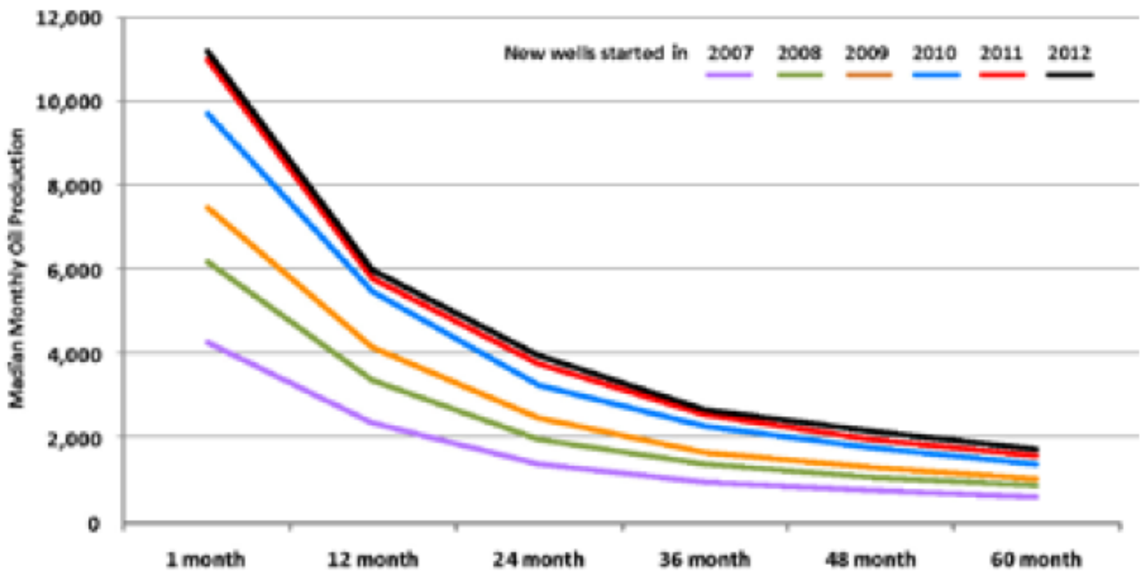


Figure 2-8 Bakken-Three Forks: per well production and decline curves overt ime, 2007-2012 (Maugeri 2013)

This rapid decrease in production rates is a technical property that creates what Maugeri calls the need for a constant “drilling intensity” to maintain the production rate over time. This requirement of constant investment, joined with the relatively high overall costs, makes the unconventional exploitation vulnerable to both price drops and environmental opposition in new and populated areas (Maugeri 2013). This will be subject of analysis in the following chapters, but the price fall that began in the second half of 2014, when prices dropped more than 50% in less than six months, provides the scenario of analysis of this idea. According to the Council of Foreign Relations (2015): “By January 2015, companies were telegraphing their intentions to reduce shale operations, with ConocoPhillips, the largest U.S. exploration and production company, planning to cut capital spending by 20 percent by deferring shale projects. And many shale producing companies have also incurred major up-front debt—the sector is more than $160 billion in debt—which could constrain the ability of smaller companies in particular to continue financing exploration and production in the event of sustained low prices.” Surely this period of volatility and falling prices led to changes in expectations, which a priori seem difficult to assess. The particular impact of this phenomenon in the Argentine case will be developed in Section 2.1.3.

As will be discussed in the followings chapters, the most important socio-economical impact of the unconventional natural gas activity in the US has been lowered energy costs, as well as prices, for a wide range of goods and services, especially for manufacturers in energy-intensive industries like energy-related chemicals, petroleum refining, aluminum, glass, cement, and the food industry. These industries “are expected to invest and expand their US operations in response to declining domestic prices for their energy inputs” (IHS Report 2013). According to the same report, the lower natural gas prices will increase the industrial production by 2.8% by 2015 in the US and benefited the consumers (due to lower energy bills) by a $1,200 a year per household saving in 2012. Regarding employment, the projection is that as many as 250,000 jobs may be directly created due to the shale boom by 2020 in the US and almost 3.9 million jobs considering the unconventional oil and natural gas value chain and energy-related chemicals activity by 2025. In terms of GDP, in 2012 the unconventional activity contributed $284 billion and the tax revenue from 2012 to 2025 will exceed $1.6 trillion.

In terms of regional development, North Dakota, with an increase in crude oil production of 5 times between 2007 and 2012 and 3 times of natural gas production, saw its real GDP per capita increase by nearly 54% in the same period, when the national US average was -0.2%. In 2013, North Dakota had the highest real GDP growth in the nation with 9.4% followed by Texas with 3.7% (US BEA). The interesting fact is that by 2001, North Dakota's GDP per capita was well below the US average (-18%), ranking 38th out of 50 states; in 2013 it was substantially above the average (+40%), ranking 2nd of 50 states, just below Alaska that also has energy-related natural resources (US BEA). This radical change in the productivity of the economy of this state was due to the shale boom.

This revolution also changed the energy export outlook of the US, from analyzing new foreign suppliers of natural gas in 2008 to become an exporter through the construction of five liquefied natural gas (LNG) terminals in 2015 (Council of Foreign Relations 2015).

2.1.2. SHALE RESOURCES OUTSIDE THE US

There are several shale formations around the word in addition to the ones in the United States (Figure 2-9). Particularly, the report prepared by Advanced Resources International (ARI) for the U.S. Energy Information Administration (EIA) that was released on June 2013 revealed that more than half of the world's shale oil resources are located in Russia, China, Argentina, and Libya. This report evaluated 137 shale formations in 41 countries outside the United States and has been, since its release, a primary source for several studies around the world.

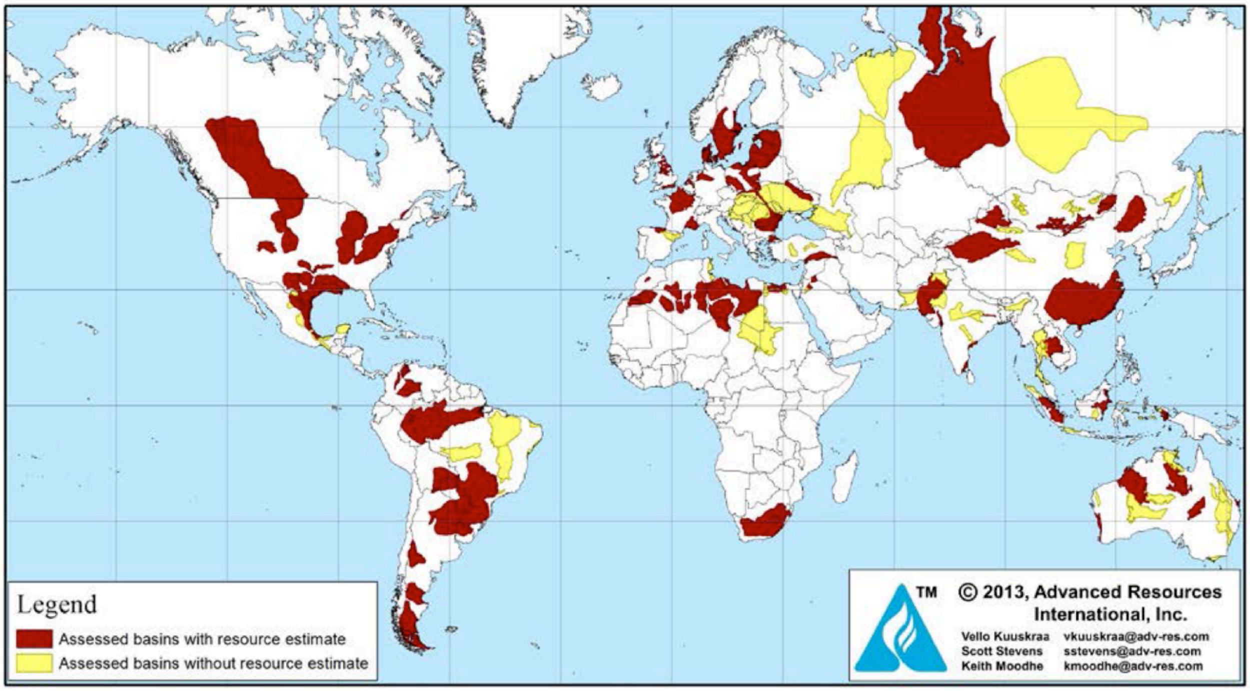


Figure 2-9 Map of basins with assessed shale oil and shale gas formations, as of May 2013 (EIA 2013)

At the same time, it is important to put in context the amount of technically recoverable shale resources versus the total proven reserves by country, to see the situation in perspective (Table 2-1). This is because obviously the shale oil and shale gas are only part of the total world's hydrocarbon resources. Particularly, it is important to mention that for the EIA the "technically recoverable resources" are: "those that are producible using current technology without reference to the economic viability thereof."

Table 2-1 Top-10 countries with technical recoverable reserves shale oil and shale gas resources (2013) and their total crude oil and natural gas reserves (2014). (Author with data from EIA).

	Shale Oil Technically recoverable resources		Crude Oil Proved Reserves			Shale Gas Technically recoverable resources		Natural Gas Proved Reserves	
	Rank Country	*Billion barrels*	*Rank Country*	*Billion barrels*		*Rank Country*	*Trillion cubic feet*	*Rank Country*	*Trillion cubic feet*
Russia	1	75.0	8	80.0	China	1	1115.0	11	155.4
United States	2	58.0	11	36.5	Argentina	2	802.0	36	13.4
China	3	32.0	14	24.4	Algeria	3	707.0	10	159.1
Argentina	4	27.0	31	2.8	United States	4	665.0	4	338.3
Libya	5	26.0	9	48.5	Canada	5	573.0	19	66.7
Venezuela	6	13.0	1	297.7	Mexico	6	545.0	31	17.1
Mexico	7	13.0	17	10.1	Australia	7	437.0	24	43.0
Pakistan	8	9.0	52	0.3	South Africa	8	390.0	#N/A	#N/A
Canada	9	9.0	3	173.2	Russia	9	285.0	1	1688.0
Indonesia	10	8.0	28	3.7	Brazil	10	245.0	33	16.2
World Total		**345**		**1655.6**	**World Total**		**7,299**		**6972.5**

The relative position of Argentina in the shale gas raking (2nd or 3rd) depends on the resources estimated for the US. According to EIA (2013), Advanced Resources International, Inc estimates

1,161 Tcf and the same EIA estimates 665 Tfc, but this last value was used for "ranking order" in the mentioned report.

Table 2-1 suggest that various parts of the world have the potential to develop these resources, even if it has not happened massively yet. There is a genuine debate about whether the US boom can in any case be replicated abroad; Maugeri (2013) arrives at the conclusion that "the expansion of the shale phenomenon in other parts of the world [will be] improbable – at least in this decade". He based his argument in the identification of those he thinks are the pillars of the US shale industry that would be difficult to replicate abroad:

1. Availability of a large number of drilling rigs, specialized crews, tools and capabilities to achieve the "drilling intensity" required
2. Private mineral rights that facilitates rapid exploration and development
3. Existence of a large number of independent companies willing to take higher risk and experiment
4. The location of the shale formations in low-populated areas
5. Strong domestic financial institutions, venture capital and private equity firms
6. Existence of midstream and downstream infrastructure (pipelines, storage, refineries)
7. Existence of adequate water supplies.

Others experts believed that some of these characteristics could be addressed by "functional equivalents" (Citibank 2014) particular to each country. For example to achieve the agility required (point 3), some large oil companies are acquiring small companies[6] or creating joint ventures (JV) abroad. Also, the service sector is seen as a potential key for spreading the revolution globally. In any case, a more detailed analysis of these points and their "functional equivalents" is developed for the Argentine case in Section 2.1.4. Now, we move forward describing of what had happened in the rest of the world.

In Europe some countries have adopted bans on hydraulic fracturing based on environmental concerns: for example France has repeatedly ruled out exploration but in a context with very low potential for this resource and a strong (and influential) nuclear energy industry. The United Kingdom and Poland have been more dynamic in the development, but the first results were in some cases disappointing. Particularly in the case of Poland, the low level of drilling activities (55

[6] For example ExxonMobil acquired XTO Energy (2010), Statoil acquired Brigham Exploration (2011) and ConocoPhillips acquired Burlington Resources (2006).

wells drilled through 2013) makes very difficult to achieve a massive development in the short term (Kleinsberg 2014).

China, with as much shale energy resources as Canada and the US combined, has been struggling in the last years with very difficult mountainous terrain with very deep and hard to fracture rocks, water shortages and other technical constraint as geo-mechanical complexities (Kleinsberg 2014), along with the lack of what Morrow (2014) called "pioneers", small private entrepreneurs very willing to take more risk and do ground experimentation.

In the case of Russia, even though the resource potential is massive, the geopolitical events in Ukraine during 2014 and 2015, have delayed Russia's shale energy development. US sanctions have restricted American firms from offering hydraulic fracturing technology, equipment and service, that are crucial for any attempt to develop this resources, cutting primarily the expectations of the main US oil service companies that were required to move their equipment out of the country (Reuters 2014). Until this geopolitical situation changes, it would be difficult for Russia to develop their resources.

The case of Argentina is different: with an incipient activity, Vaca Muerta (VM) has already achieved in 2014 the position of second largest non-conventional field in the world outside the US and Canada (Bloomberg 2014c). This is also visible in Table 2-2 that shows the number of wells drilled by country in 2013. With well-known geology and some geochemical data, the technical considerations are favorable, even though the higher perceived risk is the political-institutional one (The Economist 2014 and Bloomberg 2014). The initial results of the joint venture between Chevron and YPF in Loma Campana are also encouraging, even though there are a number of challenges ahead. As was mentioned before, the particular considerations of the Argentine case are discussed in Section 2.1.3.

Table 2-2 Estimated number of shale gas and tight oil wells drilled in 2013 (Author with data from Kleinberg 2014)

Country	Number of wells drilled	Type of product
US and Canada	15,000	Gas and oil
Argentina	200	Mostly oil
China	200	Mostly gas
Australia	30	Mostly gas

Russia	20	Mostly oil
Saudi Arabia	20	Mostly gas
Poland	10	Mostly gas

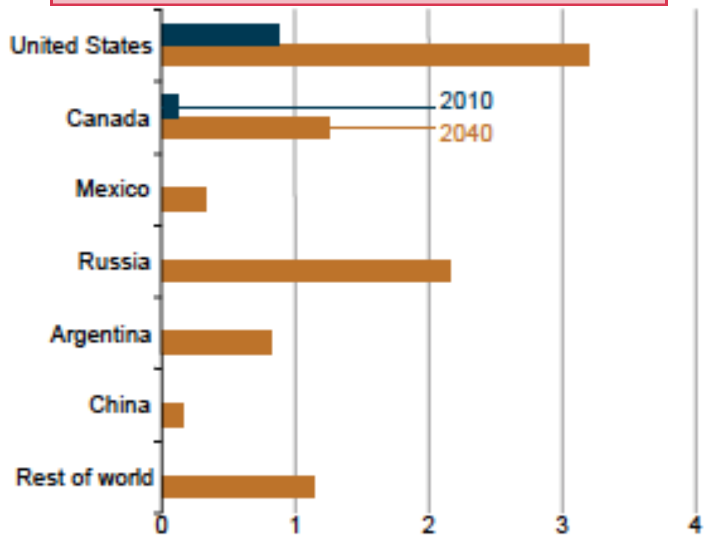


Figure 2-10 World shale oil production in the Reference case, 2010 and 2040 in million barrels per day (EIA 2014)

Up to this point, the shale energy has been introduced through its technical and economic characteristics, going from the development of the resource in the US to the opportunities abroad. In Section 2.1.3, the Argentine oil and gas sector is analyzed, along with a more detailed description of the shale energy resources available.

2.1.3. Oil and Gas in Argentina and the Shale Energy Development

2.1.3.1. From the beginning of the industry until the nationalization of YPF in 2012

As in others countries, the history of the Argentine oil and gas sector is closely related to the vicissitudes of politics. In 1907, in a context of a strong economy and development of the country, oil was first discovered in a well drilled by public officials searching for water[7] in Patagonia, near the city of Comodoro Rivadavia.

Actually, even though 1907 is recorded as the birth of Argentina's oil industry, since the 1860s there were a variety of private enterprises looking for kerosene, the main input for lighting, a

[7] Several authors discuss whether the discovery of oil was due to a fortuitous event or not. I think worth mentioning that the Comodoro Rivadavia perforation was within a geological study of the nation subsurface, decided by a Presidential Decree to identify potential resources (Decree of October 25, 1904), which was defined as a state policy. Within this framework, it may be possible that the Comodoro Rivadavia well have been a priori driven by the lack of water in the area (Gadano 2006), but I think should not be considered a lucky isolated activity.

product with considerably increasing demand. These private initiatives were inspired by the early experience in North America where a few years before Colonel Edwin L. Drake started the American oil industry with his discovery in Titusville, Pennsylvania. However, as Gadano (2006) describes, the **absence of public infrastructure** (especially transportation) and the geological complications, led to these private enterprises to not have much success. The most emblematic case was the "Compañía Mendocina de Petróleo" founded by Carlos Fader, who between 1885 and 1897 managed to drill 30 wells and produce 8000 tones of oil (Gadano 2006), before finally leaving the business in 1897. There were other causes, at the end even though Argentina was the main fuel market of America outside the United States, its limited size made it difficult to develop an industry that required this high and risky investment.

Interestingly, the intimate relationship between the railway infrastructure and the development of the oil industry dates back to its beginning. Argentine nationalists have even touted the idea that by the end of the nineteenth-century there was a "boycott" of the railway companies (owned by British capital) to obstruct the development of the Argentine oil industry favoring coal imports from England. Even though this does not seem to be completely accurate, this notion reaffirms the basis of this thesis: since the beginning there was an undeniable relationship between the development of the oil industry and transportation infrastructure.

The Argentine Congress passed the first legislation on the extraction of natural resources in 1886, under the name "Mining Code", and before that all activities were conducted without specific legislation. Even though it was a very incipient activity, the legislation of that time already regulated two key elements that would be then the focus of future disputes: who owned the resources and who would be responsible for exploiting them? This regulation stated that the owner of the resource was the state (federal or provincial, depending on the location) and the private sector was responsible for the exploitation through perpetual mining concessions without any specific royalty payment to the government, with an explicit ban on the public sector from entering into this activity (Gadano 2010). This market-oriented environment generated different exploration activities across the country.

The idea that the subsoil resources were owned by the state was inherited from the Spanish legislation (as opposed to what happened for example in the US); however when drafting the Mining Code (National Law 1919 established on November 25, 1886), there was a debate about which of the jurisdictions (national or provincial) was the owner. Finally, the federal vision prevailed stating that the resources were owned by the provinces or (as an exception) by the national state only if it was found in national territories (like the Comodoro Rivadavia discovery).

But the growing importance of hydrocarbons, particularly since this resource was seen as strategic for the defense and the economic development of the country, began to promote the idea of the need for state presence in the oil business. This led first to promoting and financing geological studies to identify the natural resources available (water, coal and fossil resources). With the 1907 discovery in Comodoro Rivadavia in the context of these studies, this idea of state-presence led to more concrete decisions: a presidential decree restricted the private concessions within 15 miles from the place of discovery, to allow the state to perform the tasks of exploration without private interventions (Gadano 2006); this was the first step towards state intervention in the oil sector. To proceed with the public exploitation of the area, a new Petroleum Bureau was created, an embryo of the future public oil company (YPF).

The public production of the Comodoro Rivadavia oil in that period was not particularly successful, but there was a general concern in the public and the government that, due to the existing mining code, concessions gave nothing in return to the state. In fact the concessions in general were won by speculators, with the objective to then sell the rights to "real"[8] private oil companies in exchange for an upfront payment and royalties associated with the production (Gadano 2006). There was a clear problem of regulation that the government tried to control by restricting the private activity.

After World War I, two perspectives changed. For Argentina, the shortages of imported coal from England during the war produced serious troubles in the economy and revealed a weakness of the country: not having its own energy sources. On the other hand, the war had shown that oil was a strategic element for defense, in its use on aircraft, ships and military equipment. Therefore, there was an increased in nationalist sentiment towards oil development policies that led to the formation of the world's first created state-run oil enterprise[9] (Gadano 2010) that was effectively formed in 1922 under the name of *Yacimientos Petróliferos Fisicales* (**YPF**). Really, the origins of YPF date from 1910, when President Roque Saenz Peña creates a specific agency of the Ministry of Agriculture (Solberg 1982). The power of YPF increased over the next decade, sharing the market with private companies, both national and international. At the beginning, international companies had full control of the downstream activity by owning the refineries (primarily Shell and Standard

[8] "Real" oil companies as opposed to speculators who just wanted to be intermediaries, without adding value.

[9] The Anglo-Persian Oil Company (today BP) was created before as a private company and the British Government purchased a majority stake in 1913 (BBC News 1998), but YPF was the first state-oil created company (Gadano 2010)

Oil of New Jersey), until 1925 when YPF constructed its first refinery in La Plata (Argentina) under the leadership of its first CEO, General Enrique Mosconi. The La Plata Refinery was among the world's ten largest oil refineries and allowed YPF to become a vertically integrated oil company with capabilities to compete with foreign-owned oil companies (Solberg 1982).

Gadano (2010) suggests an interesting comparison of the parallel decisions made by the US and Argentina to control the power of the oil trusts, at the beginning of the twentieth century. In the US, the monopolistic position of Standard Oil was eliminated by dividing the company and promoting competition. In Argentina, the decision was to create a powerful state-owned company that was in charge of driving the development of the strategic resource in the "best national interest."

Throughout the history of Argentine oil industry, the debate between public and private exploitation of resources brought instability, and changed in both directions over the decades, leading ultimately to the poor overall performance of the industry.

Interestingly, the same General Mosconi—civil engineer with advanced training in the German Army, first CEO of YPF and father of Argentine oil nationalism—lobbied in 1929 to sell 49% of YPFs shares to private Argentine investors, arguing that this would free YPF from the "slow administrative process characteristic of state organizations" and "mobilize the spirit of national capital" that at the time was not invested. He saw the structure of the at-that-time Anglo-Persian Oil Company (now BP) as an example to avoid the bureaucracy, politics and capital shortage facing state enterprises like YPF (Solberg 1982).

From the late nineteenth century to the mid-1930s, private enterprises played an important role in the oil production of Argentina through existing mining concessions. By 1934, the private companies produced 63% of the Argentine oil and by 1937 refined 65% of the total (Gadano 2010). But the local entrepreneurs changed their role in the late 1920s to a more speculative one, just looking to sell the rights to foreign companies for a fixed amount or a production royalty (Gadano 2010). This ultimately led to a transformation of the private sector to include only foreign companies, which had increasing national public resistance. This process led to the passage of specific laws affecting the oil sector in the late 30s driven by the new nationalism and producing the consolidation of the quasimonopoly of YPF in the exploration and exploitation. The delivery of new concessions was suspended and price controls and export restrictions were imposed. Even though the private concessions given under the old legislation were not expropriated, these companies were not allowed to work in new areas, leaving them virtually out of business. The private (generally foreign) companies were relegated to secondary activities, under the control of YPF (Gadano 2006).

In the early 40s with Peronism in power, oil fields were nationalized under YPF control, creating a state monopoly. By 1953, the market share of private companies had dropped significantly to 11% in production (it was 63% in 1934) and 32% in refining (it was 65% in 1937) (Gadano 2010). However, YPF had no technical and financial capacity to develop oil exploitation in a geologically complex country like Argentina. At the end of his second term, Perón was under pressure from huge expenses for imported energy and reversed his earlier policies: he tried to attract foreign investments by service-contracts with international oil trusts, which eventually were suspended after the fall of the government (Gadano and Sturzenegger 1998).

After the elections, Frondizi became to power and in 1958 implemented an aggressive program to incorporate private capital into the oil sector, through the use of exploitation and drilling contracts, allowing YPF to keep the domain of deposits and oil produced (Gadano 2010).

The results of this "mixed" stage were striking: between 1958 and 1962 production grew 30% per year, reserves increased by 50% and in December 1962 Argentina reached the desired "self-sufficiency" (Gadano and Sturzenegger 1998). Despite the numbers, the Frondizi policy endured heavy criticism and the government fell again by a military coup, and in 1963 the new constitutional president Arturo Illia revoked the contracts.

In 1967 a new Hydrocarbons Law was enacted, which remained in force, with a few modifications, until 2014, as will be discussed in Section 2.1.3.3. While the state maintained control of the exploitation through YPF, the law allowed the existence of private concessions. Despite this, the private investments continue to be limited until 1976. Between 1973 and 1976, in a period of extreme political turmoil in Argentina, a hostile environment for private investment led finally to the nationalization of the fuel commercialization business headed by YPF (Gadano and Sturzenegger 1998).

With the military coup of 1976, a further change was marked in the Argentine oil policy, encouraging openness to private capital. With the return of democracy in the 1980s and in the context of global financial crisis, it was basically a decade of stagnation due also to the severe domestic economic crisis that led to a process of hyperinflation in 1989.

In the 1990s, a reform of the oil sector promoted by President Menem led first to a new stage of privatization of the exploitation fields and finally the re-structure and privatization of YPF, initially through the sale of most of the shares in the international market. In that original privatization phase, 58.3% was sold to the public, the national government kept 20.3% and a "golden-share" with veto power, and the rest was divided between the oil-productive provinces and the company employees (Sang-Hyun Yi 2008). This first privatization phase was very successful in terms of restructuring the company and opening of new productive business, under the leadership of Mr. José Estenssoro as CEO.

In 1999, with the federal government immersed in strong financial struggles during the last year of Menem's second term and without the leadership of Mr. Stenssoro, who died in an unfortunate plane accident in 1995, the federal government sold first 14.99% of YPF to Repsol, a Spanish oil company, and finally, some month later, the rest of the shares held. This sell to a single private actor was contrary to the original idea during the first stage of the privatization, but the need to "increase the revenue from the sale"[10] prevailed in the decision. Some months later Repsol bought the other 85% from the national government, the provinces and the shareholders, with a 25% premium in the market-value of the share. After this operation, the new company was renamed Repsol-YPF and the decisions were now made in Madrid, rather than Buenos Aires.

Repsol was mainly a downstream oriented company and the goal with the acquisition of YPF was to become an integrated international oil company (IOC) and YPF's upstream assets were an "easy and inexpensive way" to reach it. In fact the new company leaped into 7th place in oil production and refining and 8th place in oil and gas reserves (HBS 2013).

Repsol financed the deal with debt, bringing the debt-to-equity ratio from 38% to 70%. Some economists think that this high level of initial debt generated a need to transfer dividends of economic results in Argentina to Madrid to pay debt, restricting then the availability of funds for real investments and explorations in the country (The Economist 2012).

Beyond this, at the beginning of the twenty-first century, Argentina was immersed in a strong economic recession that resulted in a political and social crisis in 2001 that brought down the government of President Fernando De La Rua. With this crisis, various laws of "economic emergency" were imposed and particularly the energy market was heavily regulated through price control and new taxes on hydrocarbon exports. These measures that originally appeared to be

[10] *The Finantial Times*, November 5, 1998. P31.

transient, were maintained during the presidencies of Nestor Kirchner and Cristina Fernandez de Kirchner, causing a real deterioration in the level of investment and industry expectations, which eventually led to an energy crisis from 2010.

Most observers believed that price control was maintained primarily for political reasons: inflation was becoming a problem, and the government of Fernandez de Kirchner did not wanted to pay the political price of removing subsidies and increasing electricity and natural gas rates. Furthermore, due to the exceptionally low electricity rates (that also produced overconsumption) and the lack of new investment, the government was forced to increase export restrictions to supply the local market, making the situation more complicated for the operators. Due to a short-term political vision, these two measures were not modified generating a systematic lack of investment that produced a sharp decline in production (Figure 2-11) and in proven reserves, affecting then the long-term energy outlook of the country. At the same time, the aggregate demand of energy increased boosted by consumption and Argentina rapidly lost its energy surplus (Figure 2-12 and Figure 2-13), requiring buying energy overseas, generating a large outflow of hard currency, as had happened 50 years earlier during Perón's second term (1955).

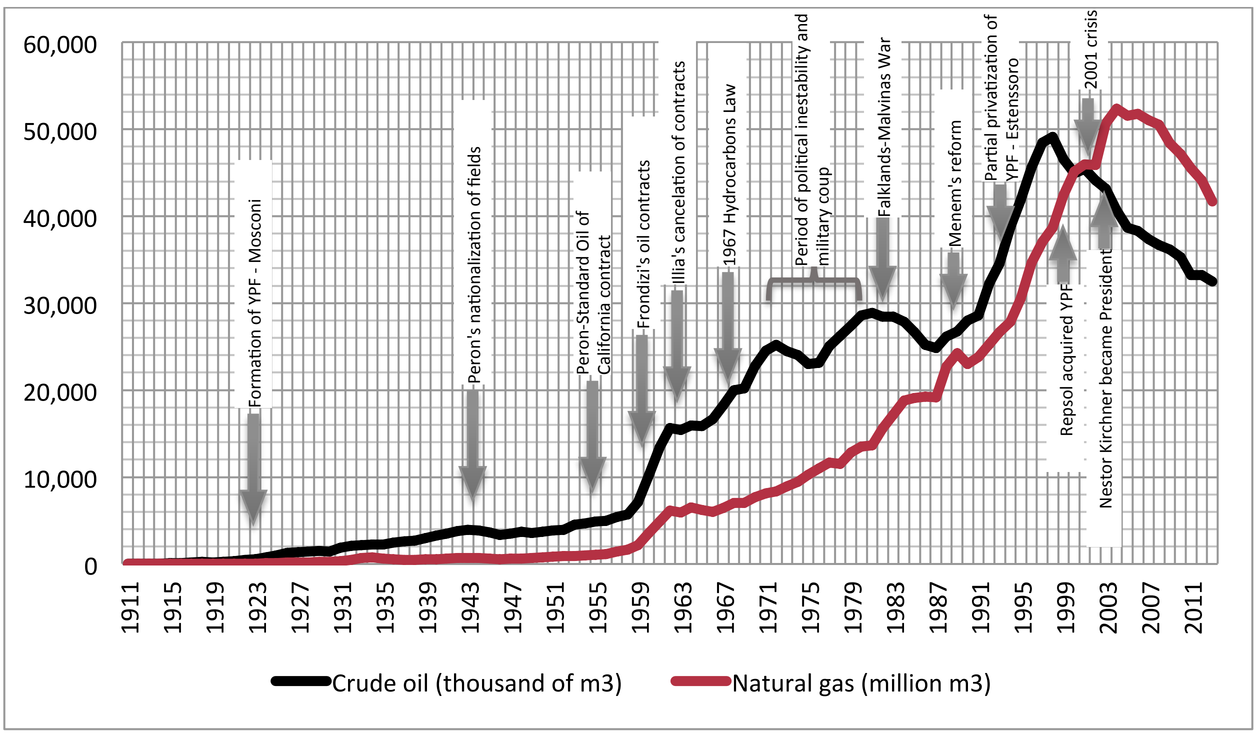


Figure 2-11 Crude oil and natural gas production in Argentina (Author with data from IAPG[11])

[11] Instituto Argentino del Petróleo y del Gas – IAPG. Website retrieved on March 7, 2015: http://www.iapg.org.ar/estadisticasnew/

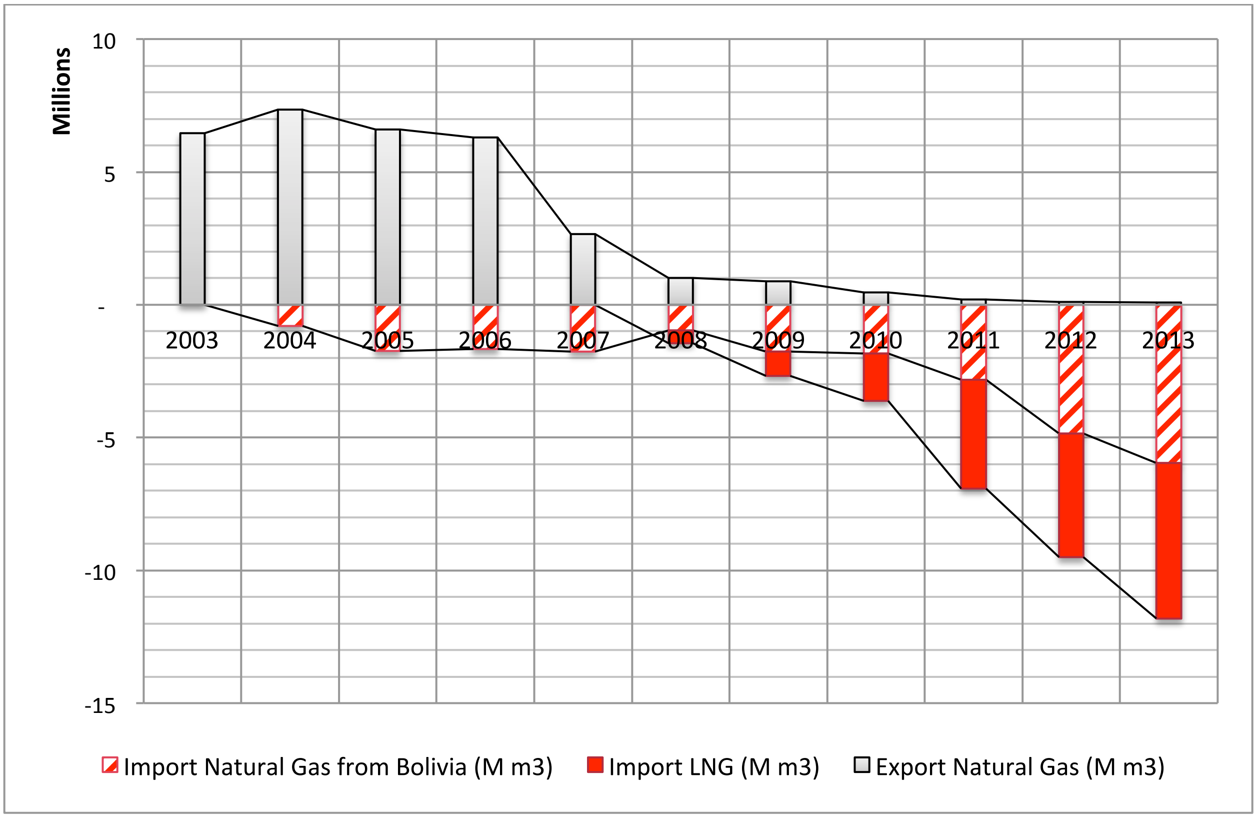


Figure 2-12 Gas - Balance of trade of Argentina (Author with data from ASoE)

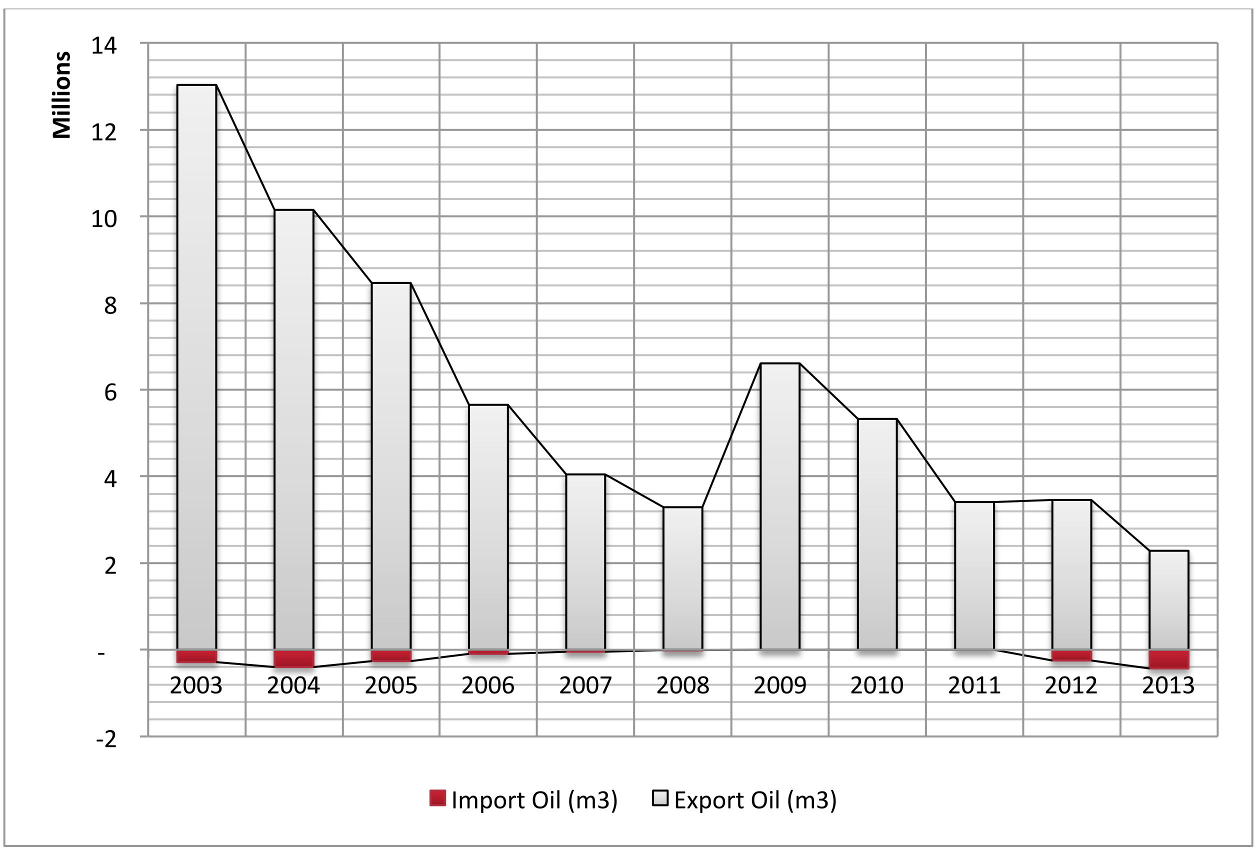


Figure 2-13 Crude Oil - Balance of trade of Argentina (Author with data from ASoE)

Market analysts and Repsol blamed the decline in exploration and production on government controls on exports and prospecting leases, and price controls on domestic oil and gas.

In this context, the political relationship between Repsol and the national government was systematically weakened over the years.

In 2008, Repsol sold part of YPF to the Eskenazi family, local capitalists with close relationship with the national government authorities in a highly leveraged transaction[12]. Some observers believed that this transaction was due to political reasons, since the new owners were seen "as a shield against government aggression" (The Economist 2012) and "experts in regulated markets" (HBS 2013). This did not cause major changes in the company strategy and actually increased the pressure of the need to transfer dividends of net profits to pay debt. In 2012, after the death of Nestor Kirchner, Mrs. Fernandez de Kirchner decided on a partial nationalization, by expropriating a number of shares owned by Repsol equivalent to 51% of the company. The Law No 26,741 approved by Argentine Congress on May 3, 2012 states in its first article: "Declared of national public interest and priority objective of Argentina achieving self-sufficiency in oil and exploration, production, processing, transportation and sale of hydrocarbons, to ensure economic growth with social equity, job creation, increase competitiveness of various economic sectors and equitable and sustainable growth of the provinces and regions."

2.1.3.2. The new era of YPF under Galuccio leadership

In objective terms, the management of Repsol as owner of YPF (between 1999 and 2011) had the following characteristics (HBS 2013):

- Production[13]:
  - Oil: production dropped -38.5%, when the national average was -18.1%
  - Gas: dropped -27%, with a national average of increasing +11.7% (Table 2-3).
- Reserves:
  - Oil: reserves dropped -65%, with a nationwide drop of -9%
  - Gas: dropped -78% when in the country was -51% (Table 2-3).
- Market Share: fell from 40% to 34% in oil and from 32% to 23% in gas.

[12] The Eskenazi family acquired the shares of YPF through a set of financial agreements provided by private banks and Repsol itself, collateralized by the same YPF shares and the commitment of distributing 90% of net income for a period of 10 years to use it to pay the debt (The Economist 2012), a similar scheme used by Repsol in 1999.
[13] Argentine Secretary of Energy Statistics between 1999 and 2011.

- Margins averaged 14.4% and dividend payout ratio was 98.1% of net income, above other oil companies (Table 2-4). This high payout ratio is related to the payment of the high initial debt from the acquisition in 1999.
- Repsol collected $15 billion dividends in the period, mainly using them to buy oil assets in other regions (HBS 2013).

Table 2-3 Production and reserves of YPF and Argentina during Repsol period 1999 to 2011 (Author with data from ASoE and HBS 2015)

	Production		Reserves	
	Oil	Natural Gas	Oil	Natural Gas
REPSOL-YPF	-38.5%	-18.1%	-64.9%	-77.9%
Argentina	-27.0%	11.7%	-9.0%	-50.8%

Table 2-4 Benchmark of distribution of dividends as % of Net Income in 2010 in local currency (HBS 2013)

	Dividends	Net Income	Dividends as % of Net Income
ExxonMobil	8,498	30,460	27.9%
BP	2,627	-3,719	--
Shell	9,584	20,127	47.6%
Petrobras	9,415	35,189	26.8%
YPF	4,444	5,790	76.8%

The government blamed Repsol of carting off profits instead of reinvesting them (The Economist 2012). But, at the same time the national government had retained since 1999 a position on the board of the company, having been then also responsible for the decisions such as investments and dividend payments.

Beyond this, the official propaganda blamed Repsol for the entire country energy deficit, and the government did not assume any responsibility. In turn, the Spanish company defended itself referring to changes in the market regulations and the hostile investment climate generated by the government.

Beyond the conflicting stances of the parties (which, paradoxically until a few months before the nationalization had had a good relationship), the conflict was resolved in 2013 when the national government agreed with Repsol the total amount of debt issued to compensate the expropriated shares.

However, the change of owners of YPF was not a marginal change in the Argentine energy sector. YPF assumed a role of "coordinator", particularly in relation to new explorations and brought a new impetus to the fallen Argentine energy sector.

With the nationalization, Mr. Miguel Galuccio was appointed CEO. Mr. Galuccio is a petroleum engineer who started his career in YPF twenty years earlier and had succeeded in world-leading oil service companies abroad, reaching positions of leadership gaining strong reputation in the sector. Under his leadership, YPF looked again like a flagship company inspired by the mixed structure of the time of Mr. Estenssoro. In fact, the shareholder structure of the companies in both administrations was particularly similar (Table 2-5), and paradoxically the company achieved the mixed structure suggested by General Mosconi ninety years before.

Table 2-5 Shareholders structure of YPF under Entenssoro and Galuccio management (Author)

	Estenssoro administration (1)	Galuccio administration (2)
	Feb-1995	*Mar-2015*
National Government	20.30%	26.01%
Oil-producing provinces (*)	11.20%	25.00%
Employees	10.00%	
Free float	58.50%	48.99%

(1) Adapted from Sang-Hyun Yi 2008
(2) YPF Investor Presentation–March 2015.
(*) The oil-producing provinces stocks are under control of the national government, that in fact control 51.01%

YPF then, assuming its leadership, began a campaign of international investors seeking to develop unconventional resources of VM (Figure 2-14), with relative success in the early years (2013-2014), as will be discussed in Section 2.1.3.5. Under this scenario, YPF declared its self not a state-owned company but a private corporation of which the Argentine national and some provincial governments owns shares (YPF–Chevron agreement presentation 2013).

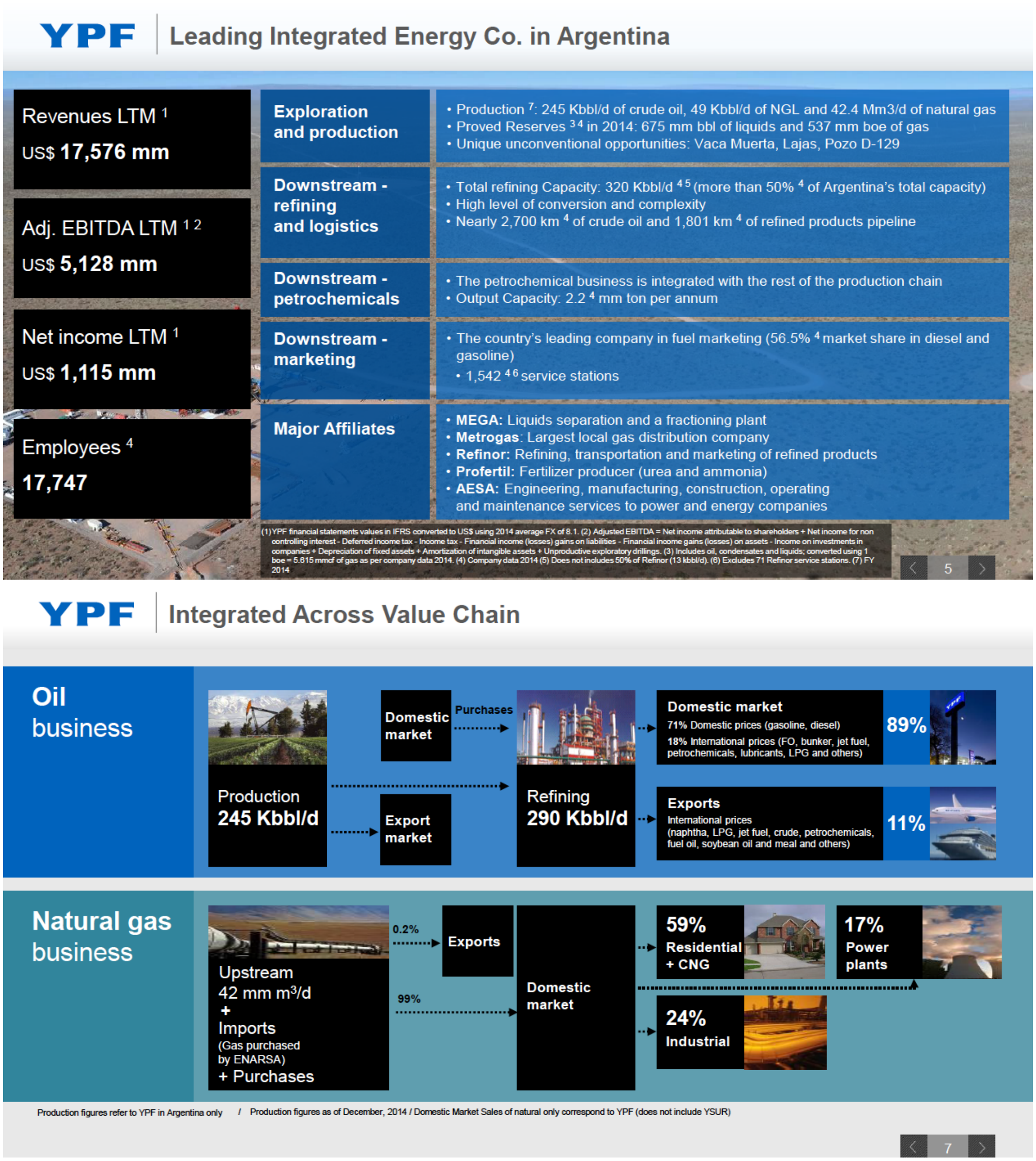


Figure 2-14 Overview of YPF (YPF Investor Presentation–March 2015)

But one of the points that Mr. Galuccio brought for discussion was the need to adapt the current Hydrocarbons Law of 1967 to be updated to the requirements of modern exploitations (unconventional and offshore) to attract the key foreign investment required. The large-scale development of VM would require between $140 billion and $200 billion (The Economist 2014).

2.1.3.3. Outdated regulation for the "new" resources

The reasons for a new regulation explained by Fernandez (2012) can be summarized as:

- **Geological:** the 1967s law mention two stages: exploration and exploitation. In non-conventional resources the main problem is to determine the technology to extract the resource, so a unified type of concession is more effective

- **Economic:** in non-conventional resources the investment curve changes, with major investments and minor production (in proportion), which drops sharply after the first year. This required lawmakers to rethink the level of royalties (12%) and concession periods (25 years).

While foreign investment was tepid following the nationalization of YPF, a joint venture announced in 2013 between Chevron and YPF to develop Argentina's shale resources suggest that investor sentiment could be improving. In July 2013, in an effort to encourage foreign investment in shale gas exploration and production, the Argentine government announced that companies would be allowed to export 20% of their production without paying export taxes and be exempt from dividend repatriation restrictions after they invest in a project for five years.

This presidential decree was then the basis of the new Hydrocarbons Law approved in October 2014 by the Argentine Congress under the number 27.007. The new law included the following changes:

- Longer concession periods:
    - Conventional resources: 25 years (as it was)
    - Non conventional: 35 years, with a pilot-phase of 5 years
    - Offshore: 30 years

      In all cases 10 years extensions are allowed.
- Royalties:
    - Basic royalties of 12% remain equal. The authority's ability to reduce royalties up to 5% depending on characteristics of exploitation (productivity, conditions, location) was maintained
    - Additional royalties (3%) in extension periods are added, up to 18%.
    - The authorities can reduce royalties by 25% in unconventional exploitation for 36 months after the application of the law, as an incentive to invest in the short term.
    - The law explicitly states that royalties are the only source of income for the provinces (controversial irregular provincial taxes are removed).
- It proposes to homogenize fiscal policy among provinces and national government.

- It specifies that the governments of the provinces and the federal state will have a new uniform environmental standards, following the provisions of the 1994 constitutional reform to "achieve the development of the activity with proper care of the environment."
- For unconventional projects:
    - Companies will provide 2.5% of the initial investment amount for Social Responsibility
    - The national government will provide an amount to be determined by the "Commission for Strategic Planning and Coordination of the National Plan of Hydrocarbon Investments" according to the size and scope of the investment project **to fund infrastructure projects** in the producing provinces (Article 21).

2.1.3.4. Argentine 2015 energy sector outlook

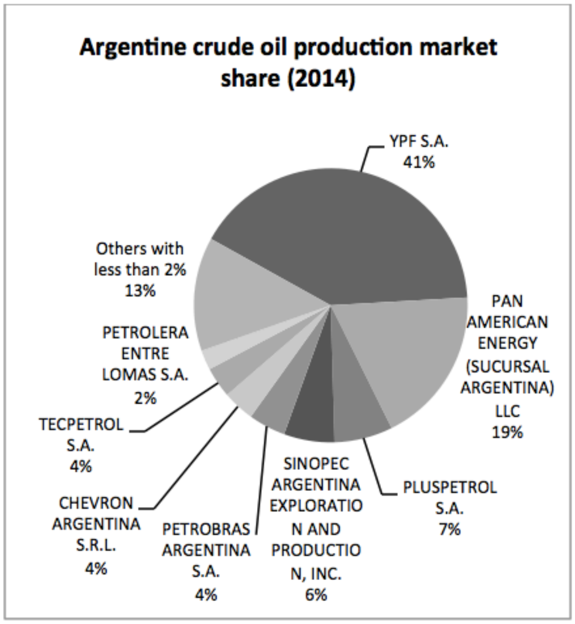
The US Energy Information Administration on its website states: "In 2012, Argentina was the largest natural gas producer and the fourth largest petroleum and other liquids producer in South America. Heavily regulated, Argentina's energy sector policies have limited the industry's attractiveness to private investors while shielding consumers from rising prices. Consequently, domestic demand for energy has grown rapidly while production of both petroleum and other liquids and natural gas has declined—leading Argentina to depend increasingly upon energy imports."[14]

There are three major divisions usually defined in the oil and gas industry: upstream, midstream and downstream. The upstream includes the exploration and production (E&P) sector. The midstream involves transportation, storage and wholesale of crude or refined petroleum products. The downstream refers to the refining of crude oil and the processing of natural gas, as well as the marketing and distribution of products derived from these.

Upstream

Regarding the upstream sector in Argentina, by 2014 YPF had 41% of market share in crude oil production and 20% in natural gas (Figure 2-15), the rest belonged to mainly private oil companies, with local and foreign participation.

[14] http://www.eia.gov/countries/country-data.cfm?fips=ar retrieved on March 3rd 2015



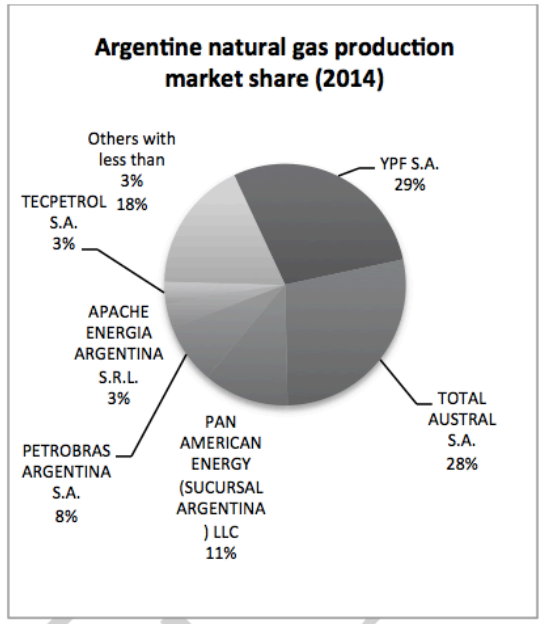


Figure 2-15 Argentine crude oil and natural gas production in 2014 by company (Author with data from ASoE)

Since the YPF's nationalization, between 2012 and 2014 the oil production of this company increased 12% and the gas production increased 14.8%, but was not able to contain the fall of others producers, which led to a fall in production at the country level of -3.5% in oil and -6% in gas (ASoE).

Even though there are 14 basins identified within Argentina, 5 are producing actively: Austral, Cuyo, Northeast, Gulf of San Jorge and Neuquén (Figure 2-16). Definitely the Neuquén Basin (where VM is located) is the most productive in terms of combined oil and gas; San Jorge is the main basin in terms of oil (Table 2-6) and Austral has significant importance in terms of natural gas (Table 2-7).

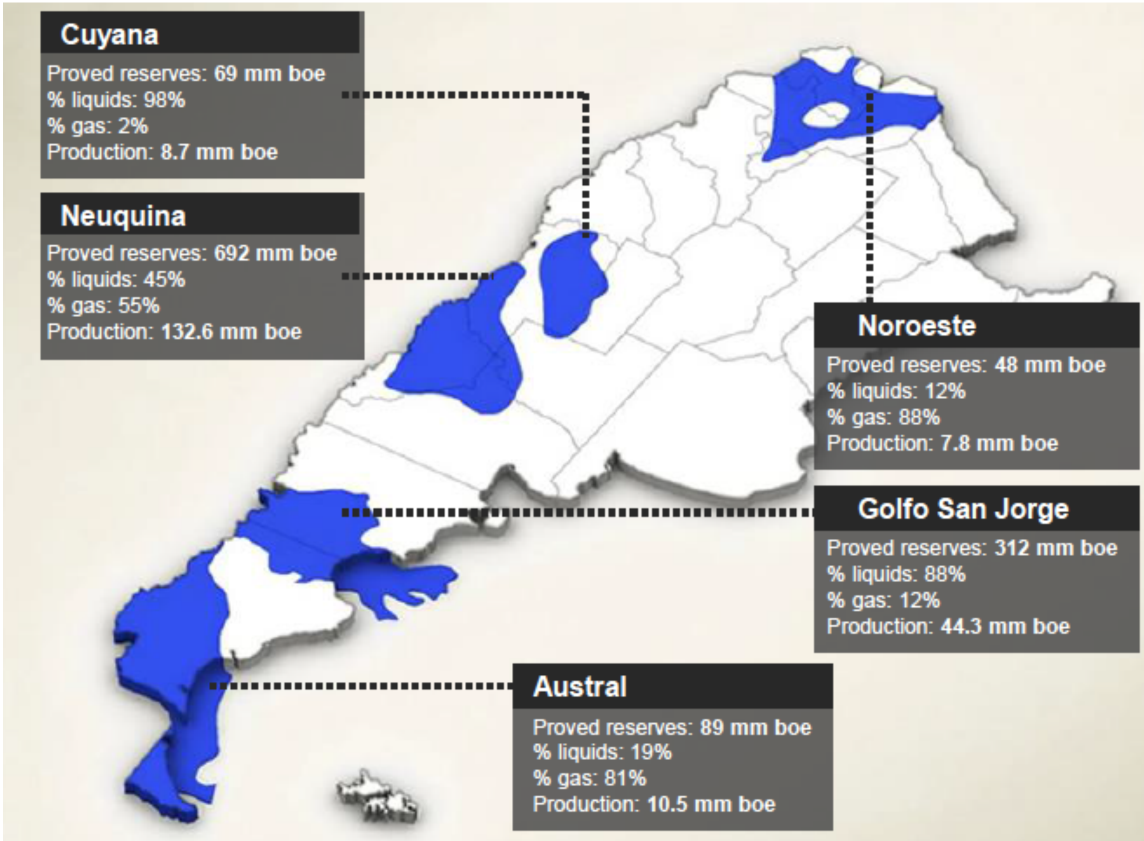


Figure 2-16 Argentine main basins (YPF Investor Presentation–March 2015)

Table 2-6 Crude Oil production per basin in 2014 (Author with data from ASoE)

		Oil Production (m3)							
Basin	Type:	2009	2010	2011	2012	2013	2014		
AUSTRAL	Off Shore	765,434	685,147	601,931	763,792	720,267	700,545	2.3%	4.3%
	On Shore	996,151	895,360	863,699	794,910	711,764	623,880	2.0%	
CUYANA	On Shore	1,914,795	1,882,904	1,871,769	1,816,417	1,753,229	1,701,693	5.5%	
GOLFO SAN JORGE	On Shore	15,801,572	15,756,992	14,673,673	15,140,031	15,030,971	15,112,612	48.9%	
NEUQUINA	On Shore	14,817,779	14,322,298	13,551,302	12,919,488	12,644,782	12,311,627	39.9%	
NOROESTE	On Shore	736,303	656,539	553,504	533,962	471,924	430,883	1.4%	

Table 2-7 Natural gas production per basin in 2014 (Author with data from ASoE)

		Natural Gas Production (m3)							
Basin	Type:	2009	2010	2011	2012	2013	2014		
AUSTRAL	Off Shore	4,396,496	5,266,853	5,882,421	6,581,889	6,534,110	6,384,855	15.4%	24.1%
	On Shore	5,521,089	5,168,858	4,935,938	4,553,515	3,979,727	3,630,408	8.8%	
CUYANA	On Shore	59,516	59,173	61,403	58,284	58,121	56,391	0.1%	
GOLFO SAN JORGE	On Shore	5,191,358	5,230,835	4,879,907	5,219,453	5,234,116	5,301,876	12.8%	
NEUQUINA	On Shore	26,970,412	25,978,767	25,159,268	23,857,753	22,642,016	23,217,003	56.0%	
NOROESTE	On Shore	6,280,379	5,403,097	4,608,616	3,852,801	3,260,199	2,893,276	7.0%	

Regarding the main players in the Argentine energy sector, YPF stands out as the leader in the production of oil and gas, as was said before. The second largest is Pan American Energy (PAE), owned by BP (60%) and Bridas Corporation (40%), which is a 50-50 joint venture between the China National Offshore Oil Corporation (CNOOC) and Bridas Energy Holdings, historically owned by the Bulgheroni family (Argentina). PAE currently operates one of Argentina's largest oil fields: Cerro Dragon (Gulf of San Jorge Basin).

Chevron (US), Petrobras (Brazil), Sinopec Group (China), Pluspetrol (Argentina) and Tecpetrol (Argentina) have a significant presence in Argentina's upstream oil production as well. Regarding the gas production, in addition to those named above, Total (France) is a key player in the Austral (including offshore exploitations) and Neuquén Basin (Figure 2-15).

Regarding the Neuquén Basin, where VM is located, the major players are YPF, Pluspetrol, Chevron, Petrobras and Total, with different importance in the oil and gas production. In Table A-1, a complete list of current holders of concessions is presented, noting that the market is highly concentrated. All the data provided in this section is from the ASoE statistics.

Midstream

Regarding the midstream, there is a relatively extensive network of pipelines for crude oil, natural gas and refined product transport through Argentina, with connections to neighboring countries.

This network has been developed in the second half of the twentieth century, originally by the state and then privatized in the 1990s reform. The crude oil pipeline network is about 3,000 km long and connects the Neuquén Basin with the major refineries in the country, near Buenos Aires, Bahia Blanca and Mendoza, and with the main ports (Figure 2-17).

YPF directly operates the majority (over 1,300 km), while Oleoductos del Valle SA (OLDELVAL) operates another's 1,000 km of pipeline (Table 2-8). OLDELVAL is a consortium of major oil companies operating in the Neuquén Basin—YPF 37%, Petrobras 23.1%, Chevron 14%, PAE 11.9%, Pluspetrol 11.9% and Tecpetrol 2.1%—formed in 1993 that has the concession for 35 years, plus a possible extension for 10 more years. This form of exploitation of public infrastructure shared between the different actors involved (oil companies) is very interesting, and will be deeply analyzed in Chapter 4 to assess the alternatives to develop new infrastructure associated with shale resources. The rest of the crude oil pipeline network segments are connections for specific purposes: to export to Chile and to supply refineries in northern Buenos Aires.

The refined products pipeline network has 3,500 km and was planned largely to supply fuels to the Metropolitan Area of Buenos Aires, the main consumption center of the country, from the refineries in Luján de Cuyo (YPF) and Campo Durán (Refinor) (Figure 2-17). YPF concentrated even more participation in this market because it has influence in the entire network: operates directly almost

1,800 km (Table 2-9) and the rest is operated by affiliated companies: Refinor (owned 50% by YPF) and Mega (38% is from YPF).

Figure 2-17 Crude oil and product main pipelines in Argentina in 2015 (Author with data from ASoE)

Table 2-8 Crude oil main pipelines in Argentina (Author with data from ASoE)

Crude oil main pipelines	Length [km]	Diameter [inches]	Operator
Puesto Hernandez - Lujan de Cuyo	525	12	YPF
Puesto Hernandez - Talcahuano (Chile)	424	16	Oleoducto Trasandino S.A.
Puesto Hernandez - Medanito	130	14	Oleoductos Del Valle S.A.
Medanito - Allen	110	16	Oleoductos Del Valle S.A.
Allen - Puerto Rosales	513	14	Oleoductos Del Valle S.A.
Plaza Huincul - Challacó	22	10	YPF
Challacó - Allen	112	14	Oleoductos Del Valle S.A.
Plaza Huincul - Allen	135	10 3/4	Oleoductos Del Valle S.A.
Puerto Rosales - La Plata	585	32	YPF
Palmar Largo - Juarez	60	6	Pluspetrol
Las Heras - Pino Truncado	71	14	YPF
Pino Truncado - Caleta Olivia	89	18	YPF
El trebol - Caleta Córdova	50.8	10	YPF
Jeppener (Brandsen) - Campana	166.5	22	Oil tanking Ebytem S.A.
TOTAL	**2993.3**		

Table 2-9 Refined products main pipelines in Argentina (Author with data from ASoE)

Product main pipelines	Length [km]	Diameter [inches]	Operator
Campo Durán - Montecristo	1109	12	Refinor
Montecristo - San Lorenzo	379	12	YPF
Luján de Cuyo - Villa Mercedes	338	16 & 14	YPF
Villa Mercedes - Montecristo	320	14	YPF
Villa Mercedes - Buenos Aires	699	12	YPF
Loma La Lata - Bahia Blanca	600	12	MEGA
La Plata - DockSud (Inflamables)	52	12	YPF
Cañadón Alfa – Frontier with Chile	3	6	TOTAL
TOTAL	**3500**		

It is unclear what exact level of capacity is currently available at these facilities, but the perception of the author, obtained by interviews and comments from industry experts, is that there is spare capacity to accommodate an increase in production. In fact this configuration of the system was used in 1998 when the historic record production was reached, when 30% more oil was produced.

Regarding the pipeline system, the network is more widespread and connects all productive basins of the country. Originally the transport network had been developed by *Gas del Estado* together with the distribution network, and was then privatized in different concessions in 1992. Since the main residential and industrial consumption is based in Buenos Aires, the gas transport pipeline network converges to there.

At the time of privatization, it was assumed that the production of gas (upstream) conceptually would behave as a free market. Therefore the transportation system was diagrammed as open access for all consumers, who would pay a toll that should reflect the cost of the carrier plus a reasonable return (comparable to that of other activity with equal risk). Any discrimination in access to transport capacity is punishable by law (Gadano and Sturzenegger 1998).

In 1992s, the existing network of gas pipelines was divided in two transportation companies: one in the north (Transportadora Gas del Norte (**TGN**) operates the North and Midwest pipelines) and one in the south (Transportadora Gas del Sur (**TGS**) operates the San Martín gas pipeline and NEUBA I and II). Geographic areas also defined the distribution market: eight distributor companies were created.

Both private companies (TGN and TGS), formed in 1992, have as shareholders a combination of operators, investment funds and free floating shares on the Buenos Aires and New York stock exchanges. The operators that own TGN are Tecpetrol (Argentina), Compañía General de Combustibles (Argentina) and Total (France) and in the case of TGS are Petrobras (Brazil) and Pampa Energía (Argentina). The remaining shares of both companies are in mutual funds or public listing.

It is noted that the transportation system is fairly organized and functions acceptably, guided by market trends. However, gas fare controls in the last decade that affected the market for gas production, also had their impact on investments in transportation and distribution networks.

In 2014, the national government through the public company ENARSA announced the construction of the Northeast gas pipeline with an investment of approximately $3.3 billion, in 3 stages. The goal is to connect provinces that currently do not have natural gas supply to the input line from Bolivia and the current TGN system.

Figure 2-18 Main gas pipelines in Argentina (Author with data from ASoE)

Downstream

As presented in the historical narrative of the Argentine oil and gas sector, the downstream also showed variations linked to the political priorities of the country. In this sense, the predominance of YPF as lead actor also varies in time, to its current rate of 50% of market share (Figure 2-19).

Currently there are 8 active major refineries, of which: 2 were built and operated entirely by private companies (Campana by Standard Oil and DockSud by Shell), 3 were built and operated by YPF until today (La Plata, Luján de Cuyo and Plaza Huincul) and another 3 belonged to YPF and were sold in the reform of the 1990s (Campo Durán, Bahía Blanca y San Lorenzo).

Regarding the commercialization of fuel, the main players are the same as in refining.

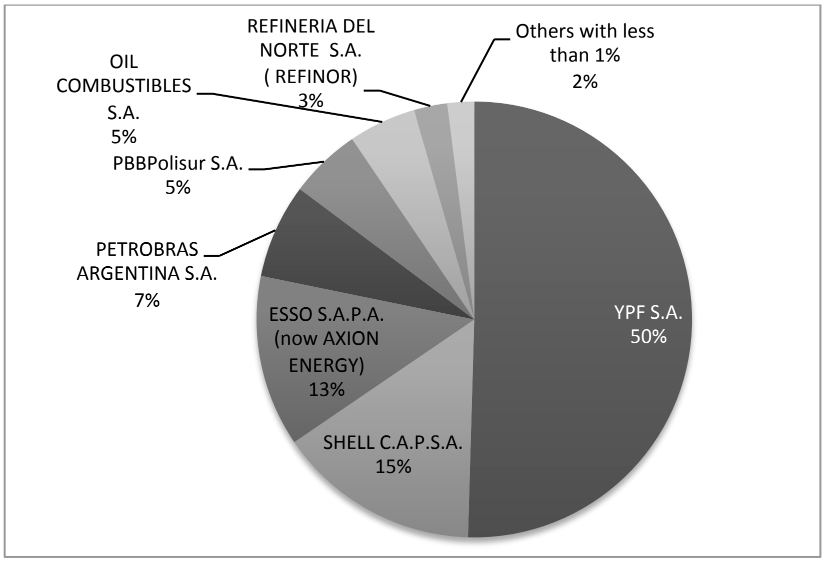


Figure 2-19 Market share in the downstream sector of Argentina 2014 (Author with data from ASoE)

Table 2-10 Main crude oil refineries in Argentina (Author from various sources indicated below)

	Refinery	Current operator	Province	Capacity (bbl/d)		Opened
A	Refinería La Plata	YPF S.A.	Buenos Aires	189,000	(1)	1925
B	Refinería Dock Sud	SHELL C.A.P.S.A.	Buenos Aires	110,000	(2)	1931
C	Refinería Luján de Cuyo	YPF S.A.	Mendoza	105,500	(1)	1940
D	Refinería Campana	ESSO S.A.P.A. (now AXION ENERGY)	Buenos Aires	90,000	(2)	1906
E	Refinería San Lorenzo	OIL COMBUSTIBLES S.A.	Santa Fe	38,000	(2)	1938
F	Refinería Bahía Blanca	PETROBRAS ARGENTINA S.A.	Buenos Aires	32,000	(2)	1926
G	Refinería Campo Durán	REFINERIA DEL NORTE S.A. (REFINOR) (*)	Salta	26,100	(1)	1960
H	Refinería Plaza Huincul	YPF S.A.	Neuquén	25,000	(1)	1919

(1) YPF Investor Presentation–March 2015 / (2) Revista Petroquímica (Magazine) November 20, 2012

(*) REFINOR is owned by YPF (50%), Petrobras (28.5%) and Pluspetrol (21.5%).

Figure 2-20 Argentine main crude oil refineries (Author with data from ASoE–letters reference in first column of Table 2-10)

Oil and gas in the context of the overall energy sector

Energy consumption in Argentina has grown in recent decades (Figure 2-21), in line with the global context. However, the composition of the energy sources has changed over the years. Figure 2-22 shows how the relative importance of natural gas increased in the overall Argentine energy consumption, particularly for electricity generation and industrial use, especially thanks to the discovery of natural gas (conventional) in Loma La Lata in the 1970s. Paradoxically the VM fields being exploited in 2015 as sweet-spots[15] are in the same area: Loma La Lata and Loma Campana, although this time the gas extracted is trapped deeper in the shale rocks.

[15] Sweetspots definition according to Shlumberger Oilfield Glossary: "Colloquial expression for a target location or area within a play or a reservoir that represents the best production or potential production. Geoscientists and engineers attempt to map sweet spots enable wellbores to be placed in the most productive areas of the reservoir. Sweet spots in shale reservoirs may be defined by source-rock richness or thickness, by natural fractures, or by other factors, using geological data such as core analysis, well log data, or seismic data."

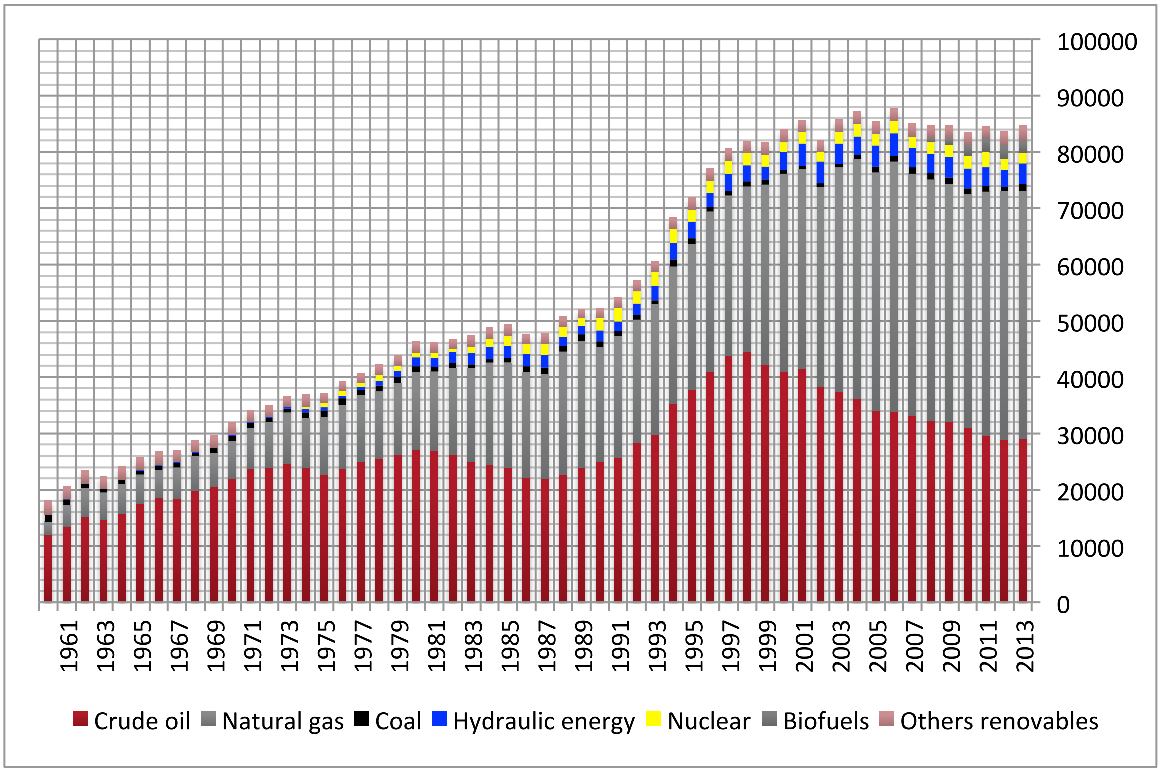
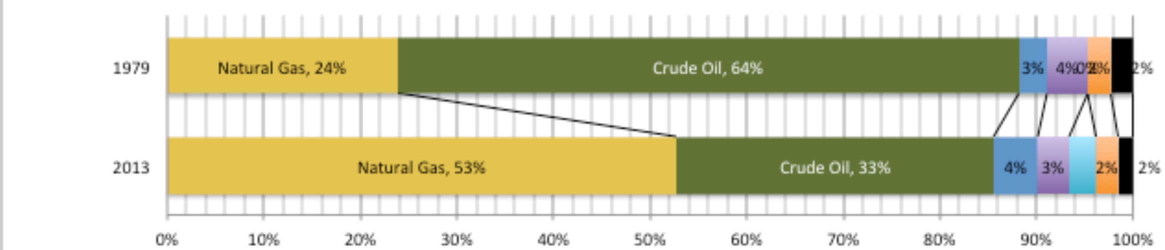


Figure 2-21 Total energy domestic consumption in Argentina in thousands of Tonne of Oil Equivalent (Author with data from ASoE)



	2013	1979
Natural Gas	53%	24%
Crude Oil	33%	64%
Hydrolic Power	4%	3%
Others	3%	4%
Biofuels	3%	0%
Nuclear	2%	2%
Coal	2%	2%

Total energy market share

Figure 2-22 Changes in the energy domestic supply between 1979 and 2013 (Author with data from ASoE)

The context of low energy prices in Argentina in the last decade that was mentioned before also contributed to low investment in renewable energy. A few new renewable projects were developed, mainly biofuels plants, but with low impact on the countrywide energy matrix.

Outside of fossil fuels, nuclear energy is the resource that had more momentum in recent years with the launch of the third nuclear power plant (Atucha II) in 2015 and the presentation of projects for the construction of two additional plants.

As for hydropower, there are two projects planned with construction contracts awarded in late 2014: Chihuido I (in the province of Neuquén, with funding from the Russian Federation, with installed power of 0.64 GWh and a construction cost of $1.8 billion) and Hydroelectric Complex Kirchner-Cepernic (in the province of Santa Cruz, funded by China with a combined capacity of 1.74 GWh and a construction cost of $4.7 billion).

In terms of electricity generation, natural gas becomes even more important in relative terms, accounting for over 56% of the total inputs (Figure 2-23)

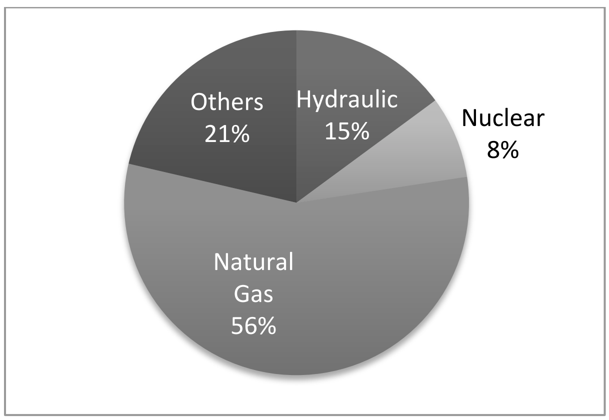


Figure 2-23 Composition on input energy for electricity generation in 2013 (Author with data from ASoE)

Seeing the importance of natural gas as an energy source in Argentina, it is clear that the increased availability of domestic natural gas extracted from unconventional wells—at lower cost than the imports—will produce a spillover effect on other industries. As mentioned previously, this effect will be particularly evident in industries that require intensive use of energy and chemicals, petroleum refining, aluminum, glass, cement, and the food industry.

This effect of greater relative importance of natural gas as an energy source is analogous to the experience in the US with the shale boom in the first decades of the twenty-first century. In fact, ExxonMobil in its Energy Outlook 2015 finds that overall demand for natural gas is projected to rise by 65% from 2010 to 2040, the largest volume growth of any energy source. The same report estimated that the proportion of unconventional gas in 2040 would be 35% of total world production, starting from 15% in 2010. In this context, interregional pipelines and LNG trade will increase globally with particular emphasis on the supply of the future main consumer: Asia. This growth in the gas demand will be produced mainly by industry (particularly the chemical industry) and electricity generation needs, and to a lesser extent for transportation fuel (ExxonMobil 2015).

2.1.3.5. The potential of shale resources. Progress to date and challenges.

As mentioned in Chapter 1, Argentina has significant reserves of shale resources that, even if there are different opinions about the actual ability to quantify them, are relevant in the global context and especially within the Argentine energy sector. A special report elaborated by KPMG in 2014 states: "Argentina is one of the countries with the strongest possibilities of producing shale resources (particularly in Vaca Muerta and Los Molles formations)."

As happened in the US, geologists knew that the source rock contained significant quantities of oil and gas, but it was unclear whether they would be commercially exploitable at some point.

The US Energy Information Administration developed in 2011 the first comprehensive analysis of shale basins outside the US where the potential of this resource was quantified. This report has been widely cited in the literature. In a second report of 2013, the EIA developed a more detailed analysis of the shale basins in South America and particularly identified 4 major basins in Argentina (Figure 2-24), 3 of which were superposed with conventional oil basins already exploited (Figure 2-16): Neuquén, San Jorge and Austral. Regarding the Paraná basin, there are particular doubts about its real potential (The Economist 2014) and commercial viability, so in the overall picture it is not particularly important.

Figure 2-24 Prospective shale basins of Argentina (EIA 2013)

As shown in Table 2-11, the Neuquén Basin has the largest preponderance in terms of potential resources of gas and oil, besides being the most studied basin in the country with a long tradition of oil and gas production. With an extension of 137,000 km² (Accenture 2012), the Neuquén Basin is larger than Greece or South Korea and almost 4.5 times the size of Belgium. Within it there are two formations: Vaca Muerta (VM) and Los Molles (LM). The footprints of both are overlapped (cover the same surface area) but underground are at different depths. Los Molles is deeper and thicker (Figure 2-25). In terms of potential, VM has the best characteristics not only for its potential volume but also because of the high quality of the resource (Mosquera et al. 2009). Regarding the quality, as shown in Figure 2-26, VM has average values of Total Organic Carbon (TOC) between 3-10% achieving a grade of "Very Good" in the Kerogen Quality scale of Shlumberger Oilfield glossary[16].

It is important to note that even assuming more conservative recovery factors of the EIA's 25% average (Table 2-11), the potential of the country's gas reserves remains high and would represent around 18 times the current proven reserves of conventional gas (KPMG 2014). This shows that this shale potential is robust according to available information.

Table 2-11 Argentine shale gas and shale oil reserves with conservative recovery factors (KPMG 2014)

Shale oil & shale gas in Argentina. 2012/2013 information.

TYPE	REGION	BASIN	SHALE ESTIMATE (*)			STANDARD RECOVERY FACTOR				CONSERVATIVE RECOVERY FACTOR			
			TCF	Billion barrels	Billion cubic meters	Factor	Billion barrels	Billion cubic meters	TCF	Factor	Billion barrels	Billion cubic meters	TCF
SHALE GAS	COUNTRY TOTAL		**3,244**		**87,588**	**25%**		**21,654**	**802**	**6.50%**		**5,693**	**211**
	Neuquén	Molles - Vaca Muerta	2,184		58,968	27%		15,741	583	6.50%		3,833	142
		Vaca Muerta	1,140		30,770	27%		8,308	308	6.50%		2,000	74
		Molles	1,044		28,198	27%		7,433	275	6.50%		1,833	68
	Chubut	San Jorge	438		11,826	20%		2,365	88	6.50%		769	28
	T. Fuego	Austral-Magallanes	606		16,362	21%		3,436	127	6.50%		1,064	39
	Chaco	Paraná-Chaco	16		432	20%		86	3	6.50%		28	1
SHALE OIL	COUNTRY TOTAL		**2.8**	**479**	**76**	**6%**	**27**	**4.28**	**0.16**	**6%**	**27**	**4**	**0.16**
	Neuquén	Molles - Vaca Muerta	1.9	331	53	6%	20	3.2	0.12	6%	20	3.2	0.12
		Vaca Muerta	1.6	265	42	6%	16	2.5	0.09	6%	16	2.5	0.09
		Molles	0.4	66	11	6%	4	0.6	0.02	6%	4	0.6	0.02
	Chubut	San Jorge	0.1	17	3	3%	0.501	0.1	0	3%	0.5	0.1	0
	T. Fuego	Austral-Magallanes	0.8	131	21	5%	6.6	1	0.04	5%	7	1	0.04
	Chaco	Paraná-Chaco	0	0.302	0.05	3%	0.009	0	0	3%	0.01	0	0

Note: (*) = including risk adjustment.

[16] Schlumberger Oilfield Glossary: "TOC" term. http://www.glossary.oilfield.slb.com/en/Terms/t/toc.aspx

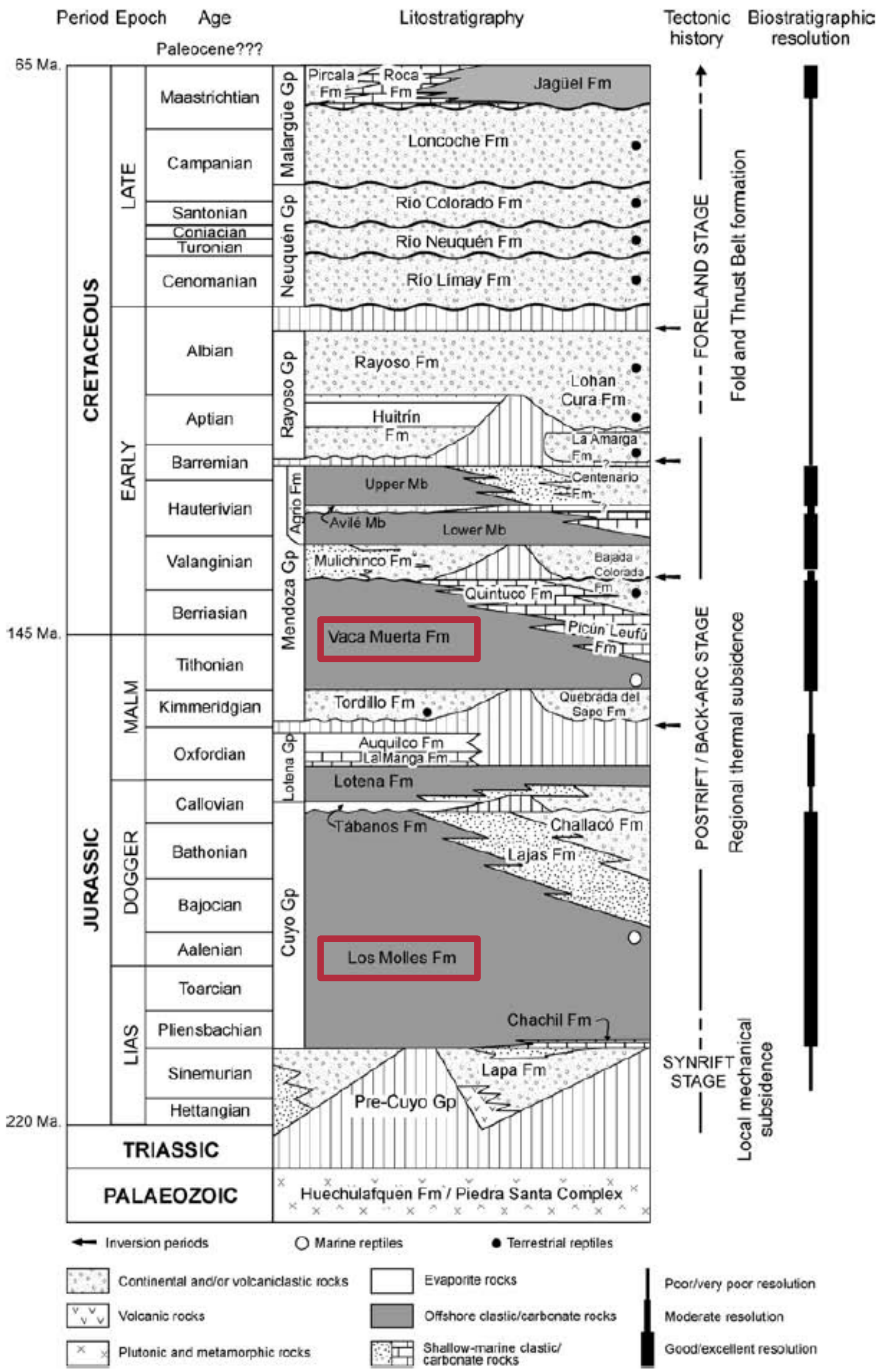
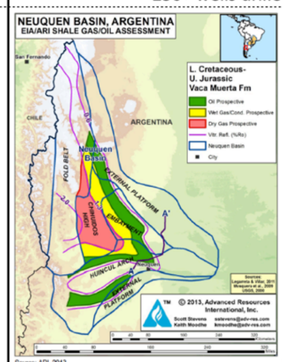
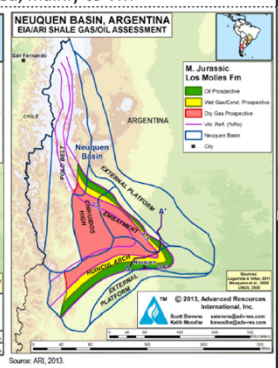
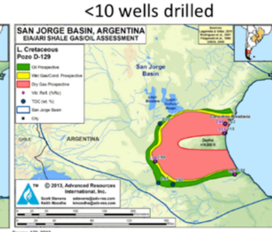
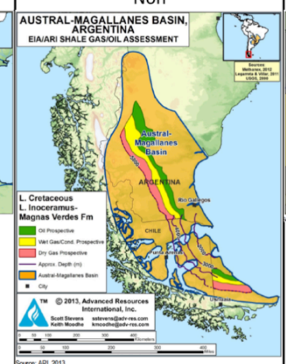


Figure 2-25 Neuquén Basin stratigraphy (Howell et. al. 2005)

Table 2-12 Shale plays identified in Argentina (Author with data from US EIA 2013b and Mosquera et al. 2009)

Basin	**Neuquen**		**San Jorge**		**Austral**	**Paraná**
Formation	Vaca Muerta	Los Molles	Aguada Bandera	Pozo D-129	L. Inoceramus	Ponta Grossa
Prospective Area (mi²)	11,660	13,270	8,380	5,580	13,530	270
Net Thickness (ft)	325	300	400	420	400	200
Average Depth (ft)	5,000 - 8,000	8,000 - 14,500	13,000	7,300 - 12,000	8,000 - 13,500	9,500
Average TOC %	5.0%	2.0%	2.2%	2.0%	3.5%	2.0%
Oil quality	High	Good	N/A	N/A	N/A	N/A
Risked OIP (B bbl)	270.4	61	N/A	16.7	131.2	0.3
Risked Recoverable (B bbl)	16.15	3.66	N/A	0.5	6.56	0.01
Risked GIP (B bbl)	1,202	982	254	184	606	162
Risked Recoverable (Tcf)	307.7	275.3	50.8	34.8	129.5	32.3
Activity	250+ wells drilled, mainly to VM		Non	<10 wells drilled	Non	Non
Map						

As usually happens in geological formations like these, the characteristics and the type of resources available (gas, oil, or both) vary considerably by location. Even if VM and LM are both source rocks, the VM shale is considered the main "supplier" of the conventional oil and gas reserves located in the Neuquén Basin, which have been exploited for the past 90 years. This shale consists of finely stratified black and dark grey shale and lithographic lime-mudstone that is 200 to 1,700 feet thick (Aguirre-Urreta et al. 2008 cited by EIA 2013b). Even if VM is thinner than the LM formation in some parts of the basin, the VM shale is richer in carbon and more widespread in the basin (EIA 2013b).

In terms of international comparison, Figure 2-26 shows the main indicators to compare US formations with VM, confirming the idea that VM is a world-class play (McGowen 2013).

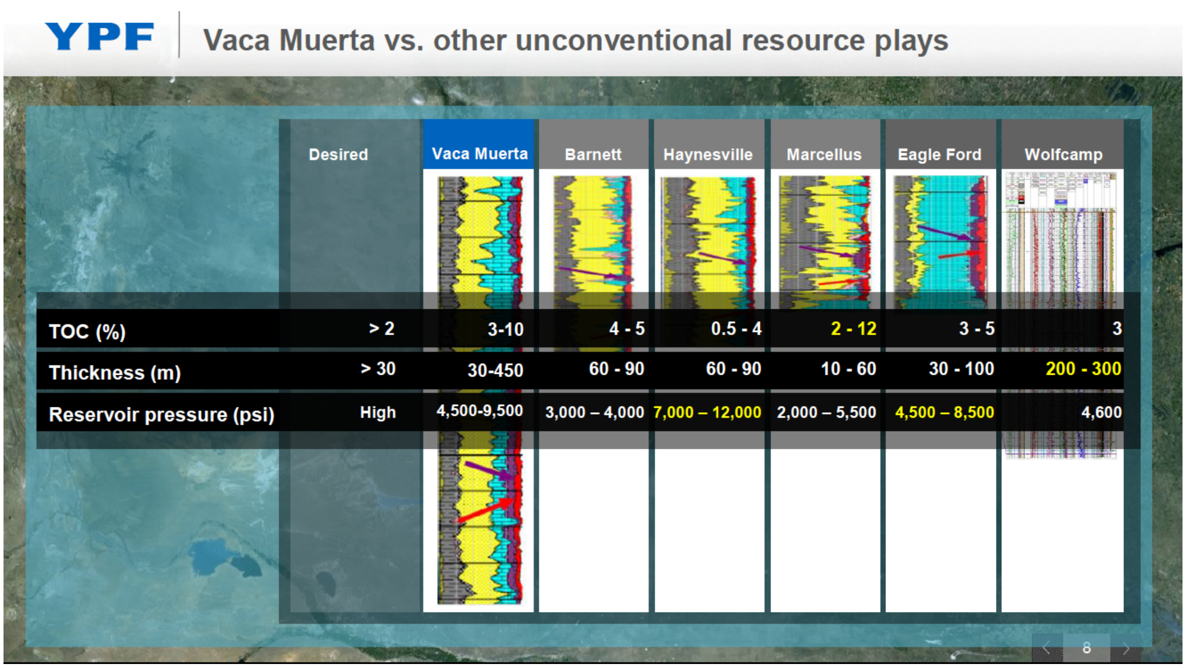


Figure 2-26 Main indicator comparison between US shale plays and VM (YPF VM Update 2014)

2.1.4. BENCHMARK OF SHALE ENERGY INDUSTRY IN THE US AND ARGENTINA

As was introduced in Section 2.1.2, there is a genuine debate about whether the US boom can, in any case, be replicated abroad in the short-term and in particular in Argentina.

Clearly the phenomenal US shale boom is irreproducible in scale and pace for several reasons–which are well explained in Maugeri's various publications (2013 and 2014)–like for example the very matured and developed oil service and financial sectors. However, the author believes that beyond this, if macroeconomic and institutional conditions are in line, there could be developments in areas where shale is available that, even without the giant size of the US, can become game-changers for their countries. It is clear that the conditions of the North American ecosystem with impeccable business environment, legal certainty, a vibrant entrepreneurial spirit, a well-developed oil service industry and large availability of shale resources, are unique, but the question that arises is whether there can be substitute forms that allow development.

The main pillars identified by Maugeri (2013) and enumerated in Section 2.1.2 cover well enough the most important aspects mentioned in the literature. So, in an attempt to move forward with a rational analysis, each of these ideas are evaluated for the Argentine context.

1. Availability of a large number of drilling rigs, specialized crews, tools and capabilities to achieve the "drilling intensity" required

A report by the Commodity Research Group of Citibank in 2014 called "International Shale Development: Can 'Made in America' Spread Globally?" mentioned that the oil service sector is seen as a potential key for spreading the revolution globally. This in fact is happening in the Argentine case, where the big service companies have been moving equipment in the last years and establishing greater presence. The rig count in the country steadily increased in 2013 and 2014 (Figure 2-27) mainly boosted by YPF, which in March 2014 announced a contract to incorporate 15 additional drilling rigs (Bloomberg 2014b), 10% of the total rig inventory of the entire country at that time.

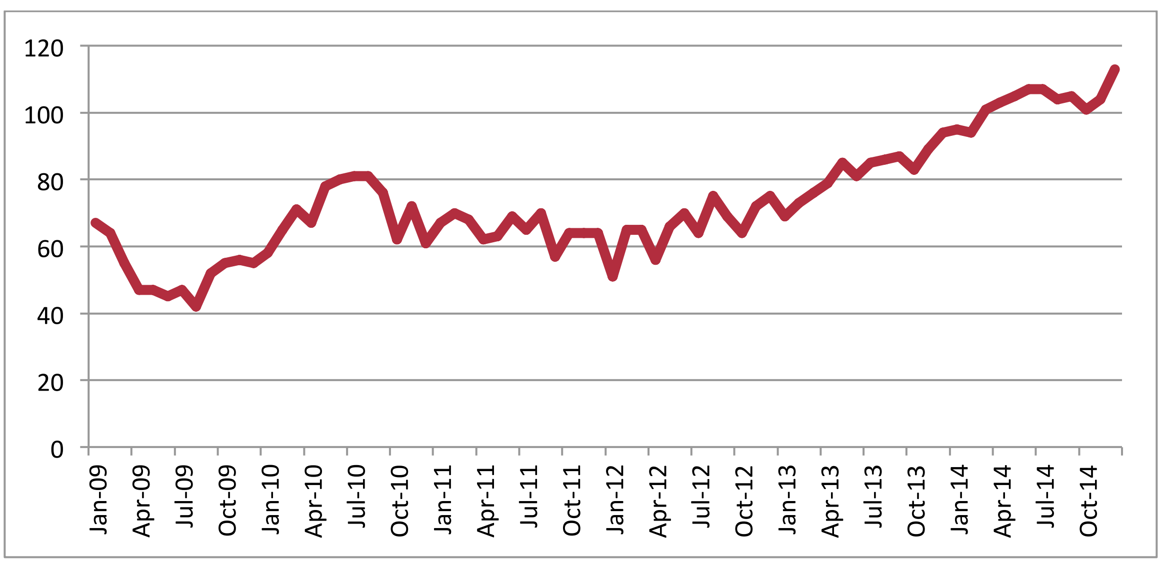


Figure 2-27 Evolution of the number drilling rigs in Argentina (Author with data from Baker Hughes website)

The oil service companies showed particular interest in the Argentine shale development. For example Schlumberger created the Latin American Unconventional Resources Center of Excellence in Buenos Aires, in the attempt to provide an integrated service to the oil companies. Also, this company argue that has the largest hydraulic fracturing fleet in the country that offers the first well completion Integrated Service (IS) package for unconventional plays in Argentina, together with “access to North American unconventional expertise and experience” (Schlumberger 2013).

Along these lines, Graham Brisben, CEO of Professional Logistics Group, argued in a presentation in Argentina in 2013 that probably the overcapacity of pumping Hydraulic Horse Power (HHP) in the US would create an “opportunity for redeployment of equipment and trained personnel to international shale plays” (PLG 2012). In fact, following his presentation, the availability of HHP went up and the equipment moved to Argentina increased steadily.

In parallel, YPF maintained a partnership strategy for the development of the unconventional resources, probably for two reasons: firstly as a way to finance the projects but also to achieve know-how of other big players. Even if many announcements were made between 2013 and 2014, YPF finally signed four joint ventures (JV) in different areas that were under YPF concession. As is shown in Table 2-13, the partnership with Chevron in Loma Campana was the main deal, which had a Pilot Phase of $1.24 billion and 130 wells in an area of 20 km^2 that started in 2013 and a second stage phase that was ratified by Chevron on April 2014 for $ 15+ billion for 1500+ wells.

Table 2-13 YPF's Joint Ventures for exploiting VM (Author with data from YPF Investor Presentation–March 2015)

Name	Resource	Partner	No. of wells	Investment
Loma Camana	shale oil	Chevron	~1.500	US$ 15 bn+
El Orejano	shale gas	Dow	~16	US$ 188 mm
La Amarga Chica	shale oil	Petronas	~35	US$ 550 mm
Rincón Mangrullo	tight gas	Petrolera Pampa	~50	US$ 550 mm

This progress in the use of American technology, through contracting service companies and the partnership with IOCs, particularly Chevron, allowed YPF to significantly reduce its operating costs per well between 2011 and 2014 (Figure 2-28).

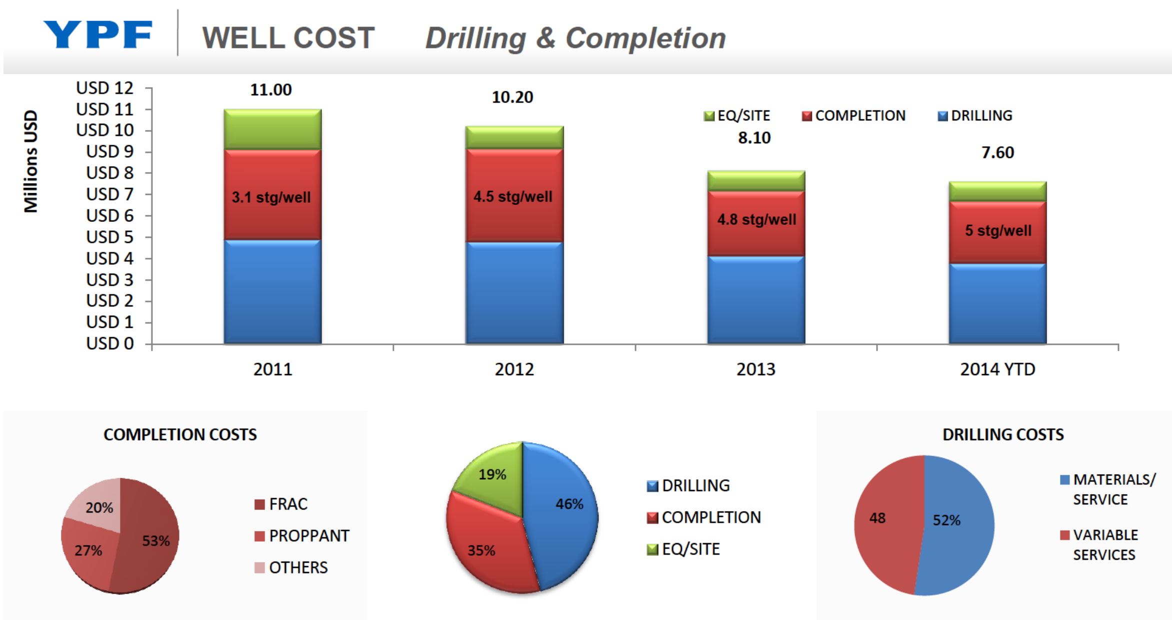


Figure 2-28 Evolution of the well drilling cost (YPF VM Update 2014)

While YPF keeps the operating position in all the areas with JV, Gas & Petroleo de Neuquén (GyP)–the provincial state owned company–preferred a contractual model called "carry" in which it retains a percentage of the JV (between 5 and 20%) but without operating or investing capital, and in addition to the regular royalties. This model, even it has been criticized because it adds an extra unproductive cost, also proved to be another way to attract the know-how and technology of international operators (such as Shell, ExxonMobil, Wintershall, Total and others). Until today, all the unconventional exploitations under these contracts are in exploratory phase.

2. Private mineral rights that facilitates rapid exploration and development

Transparency and efficient distribution of mineral rights entails an institutional challenge. In this sense, the new Argentine hydrocarbons law, discussed before in Section 2.1.3.3, was presented as a way to provide an appropriate legal framework for the development of these new unconventional resources. Clearly, given that the mineral resources are owned by the state, it is very difficult to achieve the same level of efficiency of the purely private parties negotiation process. A priori, an agreement between privates is generally easier to reach than an agreement between a private and the public sector, since this last must comply with specific regulations to ensure transparency. The speed of the private decisions is unbeatable, but at the same time a good governmental management of resources may allow more homogeneous agreements between companies by being regulated and managed by a single entity.

3. Existence of a large number of independent companies willing to take higher risk and experiment

It is true that major International Oil Companies (IOC) have not led the shale boom in the US and paradoxically are the ones that are exploring and showing the most interest in VM, beyond YPF. But, as has been observed in recent years, these companies are entering the US shale business by purchasing companies specializing in these "new" exploitations that are usually kept as separate entities to ensure the continuity of their agility and lower costs structures that have proven to be crucial for their success.

In this sense, perhaps the example of ExxonMobil in VM can show the way of what could potentially happen: after making preliminary explorations and having found a very productive well in 2014, in early 2015 ExxonMobil made a reconnaissance trip to VM[17] with its subsidiary XTO Energy, one of the largest US shale producers acquired in 2010. During this trip, it was confirmed that this company could carry out the eventual massive development of unconventional in Argentina in coming years. Maybe this sharing scheme in which the big players made efforts to obtain concessions (very common activity for them and indeed also performed in the US in the offshore concessions) and the smaller subsidiaries take the risk and experiment, as they do in the US, could be a successful “functional equivalent”.

4. The location of the shale formations in low-populated areas

VM is located in an area of very low population, such as Eagle Ford or Bakken in the US, as opposed to places as Poland or the UK for example, or even Pennsylvania in the US (Figure 2-41). So this potential impact of shale activities in populated areas is not an important point for the Argentine case.

5. Strong domestic financial institutions, venture capital and private equity firms

This is probably the weakest point of the Argentine case. Given the recent financial history of the country, even though Argentina's international public debt was 95% restructured and is considerably low, the non-accessibility to international financial markets and the political-financial events of 2014 with the dispute with the holdouts in New York courts makes it very difficult for the companies (including YPF) to get funds for such investments in the short run. Between 2013 and 2014 YPF tried to get partners and investments in foreign and domestic capital markets by issuing

[17] “Exxon. La estrategia del gigante en Vaca Muerta”, La Mañana de Neuquén, February 25, 2015.

debt with good initial results, but it did not achieved the very high level of capital required, estimated in $200 billion for the massive development of VM. As suggested by some observers (Bloomberg 2014), this point will be approached with more predictability after the presidential elections in October 2015.

6. Existence of midstream and downstream infrastructure (pipelines, storage, refineries)

As discussed in the previous section, the midstream and downstream infrastructure has a wide coverage into VM (for its history in the development of conventional hydrocarbons in the area) with some spare capacity that has remained available by the declining in production of oil and gas in the last decade. Based on this, the author believes that this point is not critical in the short term, but it definitely should be addressed in the medium term if this development reaches the desired maturity.

In terms of ground transportation infrastructure for inputs, which is the subject of this thesis, the infrastructure available is ineffective in terms of capacity, requiring strategic decisions to define the conditions and stages for new investments. This point is discussed in Section 2.2.

7. Existence of adequate water supplies.

In Neuquén, there is a quite long network of rivers—particularly the Neuquén, Limay and Colorado Rivers—controlled with dams that could provide enough water for shale development. In fact, only 0.1% of the river flow will be used for VM shale operations versus 5% used for irrigation and human consumption. The remaining 95% flows into the sea (YPF–Chevron agreement presentation 2013). Although the average water availability per person is adequate for provinces like Neuquén and Mendoza within the basin, regional water stress is still observed (Accenture 2012) and should be managed by the operators, and regulated by the governments. As was mentioned in Section 2.1.3.3, the discussion on environmental regulation is still pending and should be addressed in the short term; within this context, water regulation should also be an essential point. What we want to stand out at this point is that in physical terms, there is sufficient water availability.

2.2. THE SHALE ENERGY TRANSPORTATION AND LOGISTIC SYSTEM

2.2.1. RELATIONSHIP BETWEEN SHALE ENERGY DEVELOPMENTS AND TRANSPORTATION INFRASTRUCTURE

The massive inputs needed in shale development significantly increases the transportation and logistics requirements at the well site, in comparison with conventional exploitations. In the US it is expected that logistics and supply chain sector related to unconventional hydrocarbon, will grow from $ 145 to 206 billion by 2025, creating 233,000 new jobs. Clearly this shows that the impact on transportation and logistics system is significant and must be analyzed.

As an order of magnitude, some experts from Delloite's mentioned: "each hydraulic fracturing stage pumps about 300,000 gal of water and up to 200 tones of sand down a well. 20-40% of the fluids and solids used in hydraulic fracturing flow back to the surface as hazardous waste and require transportation to other well sites or treatment and or disposal sites. Well sites are in both remote locations and outside of developed communities with differing road and pipeline infrastructure" (OGJ 2012).

Beyond the economic impact, the US experience showed that the shale developments produce a significant deterioration of public infrastructure, particularly highways and roads. The main studies on this matter were developed by the Upper Great Plains Transportation Institute of North Dakota State University (UGTPI 2013 and 2014), University of Texas at Austin (Banerjee 2012) and Texas A&M (Quiroga et el. 2012), funded by states' DOT and the Federal Highway Administration. In general all these studies conclude with the need to identify the marginal deterioration caused by shale operations and encourage local and regional governments to act in time to avoid citizen complaints, especially from neighbors to shale operations.

Now, the question is what is different in logistics about the shale exploitations in relation to other conventional oil operations? And the answer is: inputs. All the material and equipment needed in shale operations represent very significant volumes of cargo with highly concentrated traffic over time. In North Dakota, some estimates indicated that the number of loaded trucks required for a single well drilling is over 1,000 truck-loaded trips (UGTPI 2013). The Department of Environmental Conservation of the State of New York estimated that for an 8–well pad with two rigs, the total transport volume expressed in number of truck trips varies between 5850 and 8905 trips (PLS 2012) distributed in different stages (Figure 2-29) with different preponderance of each input at each stage (Figure 2-30).

Freight that must be delivered for one multi-well pad	Required trucks
Drilling Rig	60
Drill Pad and Road Construction Equipment	10–45
Drilling Fluid and Materials	200–400
Drilling Equipment (casing, drill pipe, etc.)	200–400
Completion Rig	30
Completion Fluid and Materials	80–160
Completion Equipment – (pipe, wellhead)	10
Hydraulic Fracture Equipment (pump trucks, tanks)	300–400
Hydraulic Fracture Water	3,200–4,800
Hydraulic Fracture Sand	160–200
Flow Back Water Removal	1,600–2,400
Total	5,850 – 8,905

Figure 2-29 Volumes trucks by stage of development (Department of Environmental Conservation, State of New York, USA).

	Civil site prep/ Projects	Drilling	Completion/ Fracking	Flowback	Production
Duration (approx.)	60 days	15-60 days	15-30 days	20 days	5-40 years
~ percent of daily road volume required*	5-15 percent	5-15 percent	60-80 percent	2-5 percent	<2 percent
Activities requiring road transport	• Road construction • Site preparation • Drill pad construction	• Mobilization of drilling equipment and rigs • Waste (fluid and solid)	• Mobilization of fracking equipment and tanks • Freshwater • Waste (fluid)	• Mobilization of frack tanks • Wastewater • Removal of rig and drilling equipment in preparation	• Water tanks • Wastewater
Examples of materials/ resources transported	• Aggregate • Cement • Pipeline • Water	• Casing / cement • Drilling chemicals • Water	• Water • Proppant • Fracking chemicals	• Water • Drilling equipment	• Water

Figure 2-30 Logistics requirements by stage (Accenture 2012)

In the US, given the fragmentation of operators, for the reasons described in Section 2.1.4, the logistics market is mainly driven by competition, so the individual companies are the main actors in the planning and investment decision on the infrastructure development.

In turn, making a comprehensive analysis of the US logistics system related to shale developments, Accenture consolidated a typical operational scheme (Figure 2-31), with a description of the main modes of transportation used in the US for each type of input and output.

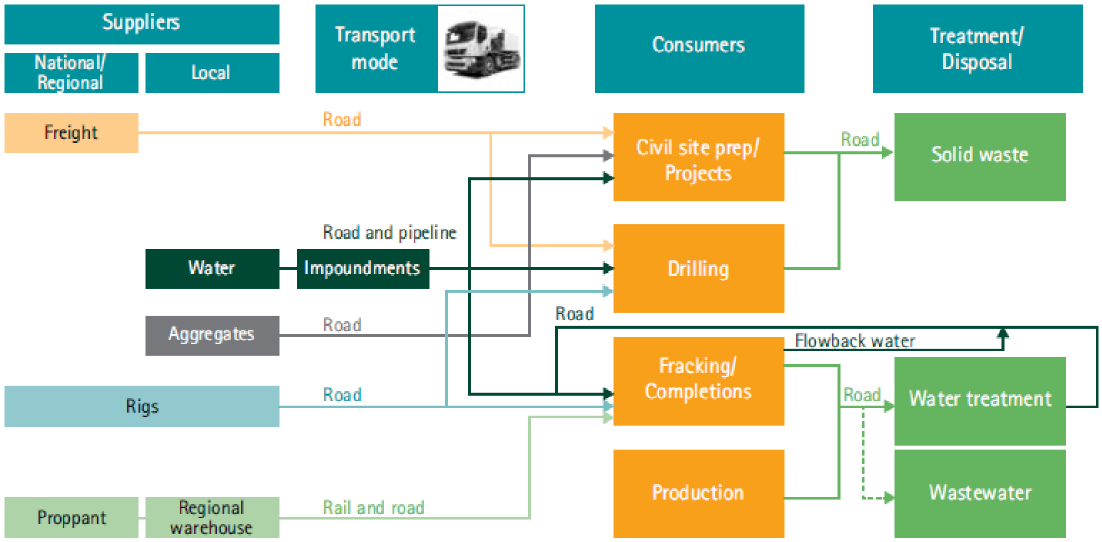


Figure 2-31 Logistics structure typical of unconventional hydrocarbon developments in the US (Accenture Logistics Marcellus Field Study, August 2011)

Meanwhile, some studies have quantified the transportation and logistics cost related to each stage of the construction of unconventional wells, by input (Figure 2-32).

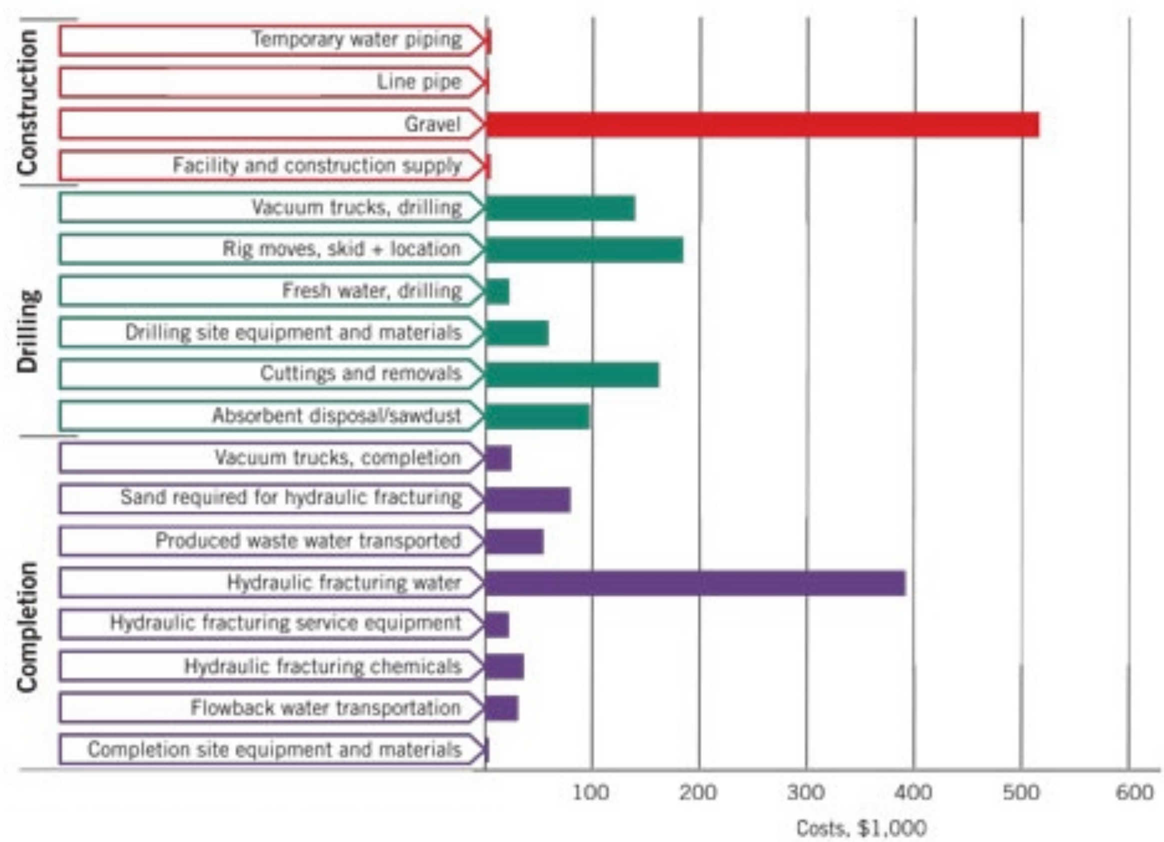


Figure 2-32 Logistics costs by material type for all wells drilled and completed on one pad (Delloite Wellsite Logistics Model 2012 from OGJ 2012)

According to the transportation volumes and distances, there are two levels of impact: local—near the wells—and regional—in the use of public infrastructure for long or medium distances transportation—(Figure 2-33). Each input has different weight on these impacts, as discussed in Section 2.2.3. For example water logistics has an important local impact because implied large volumes over short distances, while for example frac-sand has longer distances and moderate quantities, producing a regional impact.

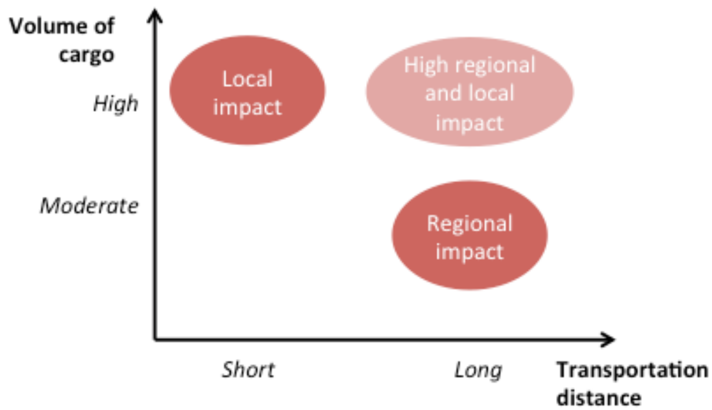


Figure 2-33 Local and regional impact according to transportation volume and distance (Author)

In a general perspective, local impact complaints are predominant in the US case, with important implications to counties and cities in the producing areas. While in the Argentine case with wells located in remote areas and on lands used almost exclusively for oil and gas exploitation, the local impact is low but there is a significant regional impact on the poor quality public infrastructure available (roads and railways), that were not designed for the levels of transport demand required by shale developments like VM.

2.2.2. THE CURRENT TRANSPORTATION INFRASTRUCTURE SYSTEM IN ARGENTINA

In the US it was estimated that the slow adaptation to new logistical challenges from suppliers of the oil industry generated extra transportation and logistics costs of 15-30% (PLS 2012). Again, Argentina may have the competitive advantage of learning about what happened in the US, taking best practices and using strategic planning at early stages.

In terms of ground transportation infrastructure (excluding pipelines), the VM area is primarily served by a limited road network and one branch of the Roca railroad under Ferrosur Roca concession, as was previously mentioned in Section 1.3.

The planning of this infrastructure in terms of geographic coverage and traffic volumes was performed over 50 years ago, with few investments since and a considerably lower transportation demand.

In Argentina in general, and in Patagonia in particular, there is a national highway system managed by the Dirección Nacional de Vialidad (DNV), an analogous entity to the US Federal Highway Administration, that acts as a backbone of the country connecting different regions. In general these are the roads with higher traffic volumes. At the next level of hierarchy there is the provincial road network, which is managed by entities similar to the DNV in the provincial governments. Maintenance and investment quality on these provincial roads varies widely throughout the country and largely depends on the funds available to the provincial entities. Finally there is a tertiary road network that may be dependent on local municipalities or, in the case of oil exploitation, the same oil & gas (O&G) companies operating the fields that maintain the roads through subcontractors.

This road system is in fact a unified network with different jurisdictions and complementary functionalities (national network has a connectivity function while tertiary has a capillary function), meaning that there is a very weak coordination of the infrastructure investment in some cases.

The main roads serving the area of VM are indicated in Figure 2-34, identifying the national and provincial systems.

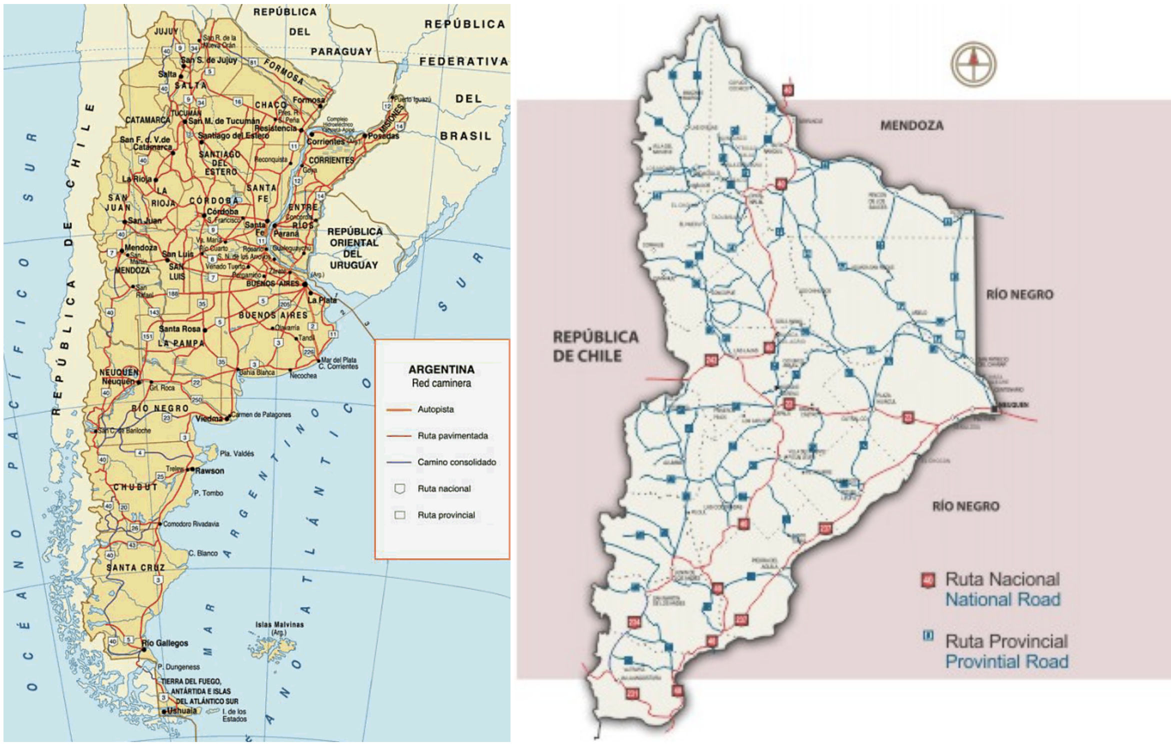


Figure 2-34 National and Provincial road subsystem (DNV and DPV Neuquén)

In the case of rail, the situation is not much simpler. In operational terms, in early 2015, the railway branch mentioned (Bahía Blanca-Neuquén) of Roca railroad is under concession to Ferrosur Roca, a private enterprise that has been responsible for the operation and maintenance of the network since 1993 (Figure 2-35). But the institutional composition of the railroad subsystem is likely to change in the coming months, as President Fernandez de Kirchner announced on March 1, 2015 a change in the railroad policy that was included then in a Law approved by the Argentine Congress on April 15, 2015, as will be seen in Section 3.3. During this work the author will assume that the institutional sphere related to the railway is very unstable in the short term, so that any intervention in the sector will require defining the institutional framework first.

Figure 2-35 Ferrosur Roca concession network (Adapted from Ferrosur Roca website)

In the context of this thesis, the term "institutional sphere" is related to the institutional system in which is embedded the physical domain. According to the CLIOS Process User's Guide (Sussman 2009): "The institutional sphere includes actors and organizations (i.e. the institutional stakeholders) that influence and affect (and are affected by) one or all of the subsystems."

The Argentine railway network was mainly developed by the private sector between 1870 and 1914, primarily financed by British, French, German and Argentine capital investors, reaching a maximum length of 47,000 km. After various economic cycles and in a worldwide scenario where the railroad was no longer the only transportation mode for long distances, but automotive transportation had increased its relevance, after World War II the Argentine government nationalized all railroads, concentrating it in a single public company Ferrocarriles Argentinos (FA).

As described for the energy sector, freight railroads were also included in the state reforms in the 1990s with the privatization of public companies. In objectives terms, analyzing the total volume of freight transported by railroad, the private concessionaires were able to reverse the decline tendency of the previous four decades under the public management (Figure 2-36). Actually the private companies were able to transport 100% more volume of cargo (in tonne[18]-km) in 2007 than the quantity transported in 1994, but failed to increase market share: that remained around 4%; trucks consolidated their broad market dominance (Martinez 2014). It is interesting to note that

[18] During this work the author will use the metric unit "tonne", equivalent to 1,000 kilograms or approximately 2,204.6 pounds.

the Argentine general opinion perceives the reform of freight railroads of the 1990s as a failure, when in objective terms the numbers indicate positive results, even if there could have been errors that should been improved.

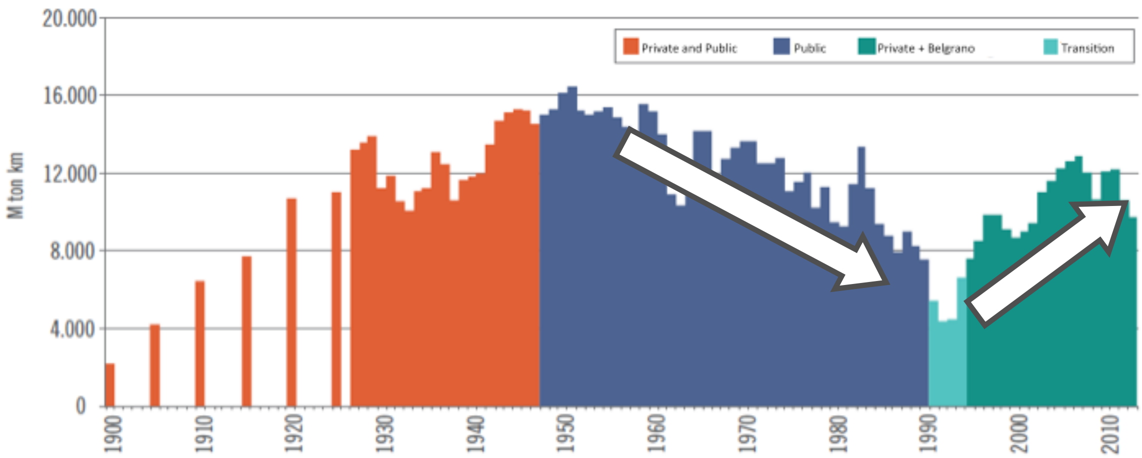


Figure 2-36 Total freight volume in railroad in Argentina (Martinez 2014)

Beyond this general discussion, in the railroad branch that will supply VM in particular, the investment level was considerably low and the level of service provided by the operating company was poor. Many observers suggest that the operator does not have special incentive to invest and develop this remote branch because of its nature. Ferrosur Roca is a subsidiary firm of the leading cement manufacturer of Argentina, which uses the Roca railway as a vertical integrated industrial logistics system to transport the cement from the production plant to Buenos Aires (370 km).

In short, the rail subsystem should be considered as an existing infrastructure with poor level of conservation that can be operated at 21 tonne per axle between Bahía Blanca and Neuquén and at 17.5 tonne per axle between Neuquén and the end of the line. As mentioned previously, the institutional context of the sector is very weak in the short term, so in the context of this thesis it will be assumed that for any of the alternatives analyzed, a new institutional context must be proposed.

2.2.3. THE TRANSPORT CHARACTERISTICS OF EACH OF THE MAIN INPUTS

As previously discussed, the forms of supply and transportation modes used vary according to each input. An analysis of the logistics of each in the US case and its application in Argentina is done in the following sections. The US logistic system is used as a benchmark since this country is almost the only massive producer of shale gas and shale oil in the world. We proceed then to the definition of the key drivers of transport demand linked to inputs for shale developments (Figure 2-37).

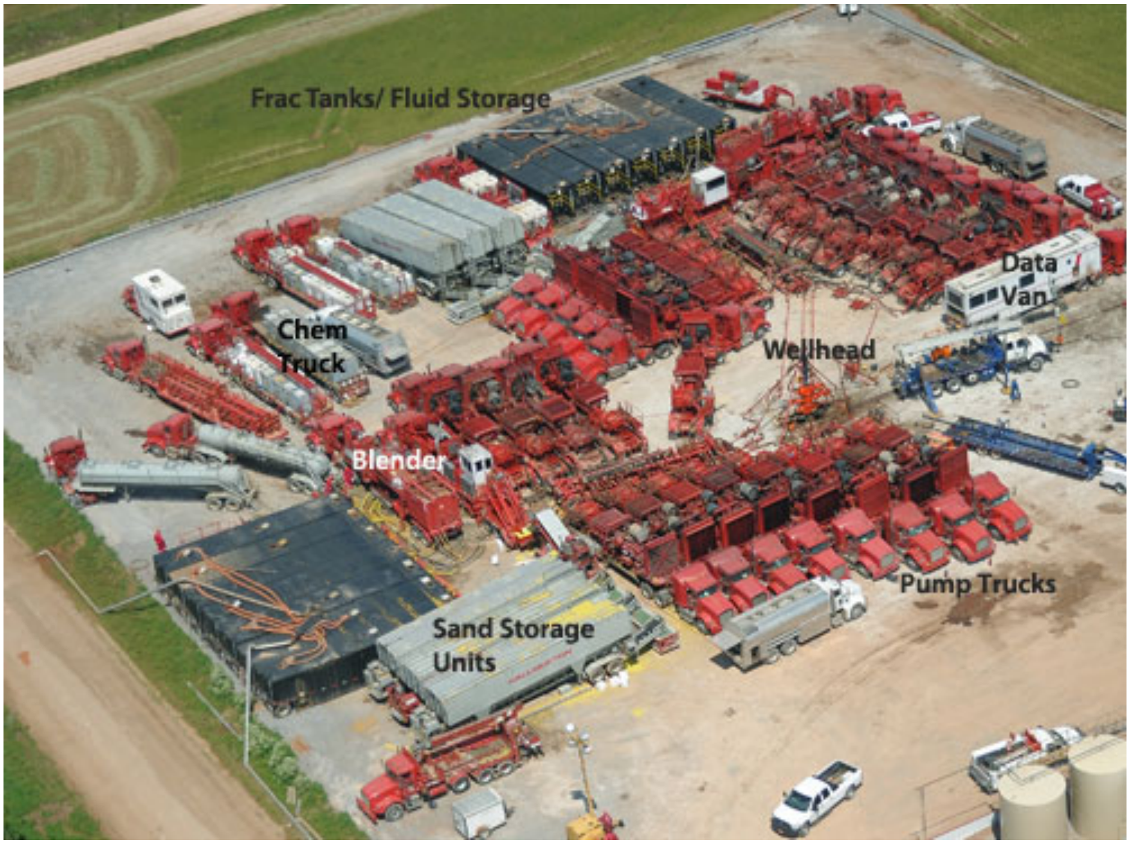


Figure 2-37 Aerial view of a well in Bakken shale (PLG 2013)

2.2.3.1. Proppant agents (frac-sand)

In the US usually the suppliers of proppant agents for hydraulic fracturing processes are also in charge of the logistics for the provision. Normally providers coordinate a logistics system that transports the material from the mines to distribution centers areas near the fields. From there, upon receiving orders from operators, trucks are dispatched to the wellheads, as shown in Figure 2-38. This means that the same providers contract the required logistics services, adding these costs to the final price of the product at the wellhead.

Logistics decisions are fragmented and suppliers do not have a strong position in the transportation market, but due to the highly developed US railroad market, the logistics turn out to be very efficient because producers are capable to reach virtually anywhere in the country through the connected railway networks. At the same time, the railway market (especially the short-line railroad) is very customer oriented, looking continuously for opportunities to grow, making it relatively simple to develop for example eventual required infrastructure for a detour to a new mine or distribution center.

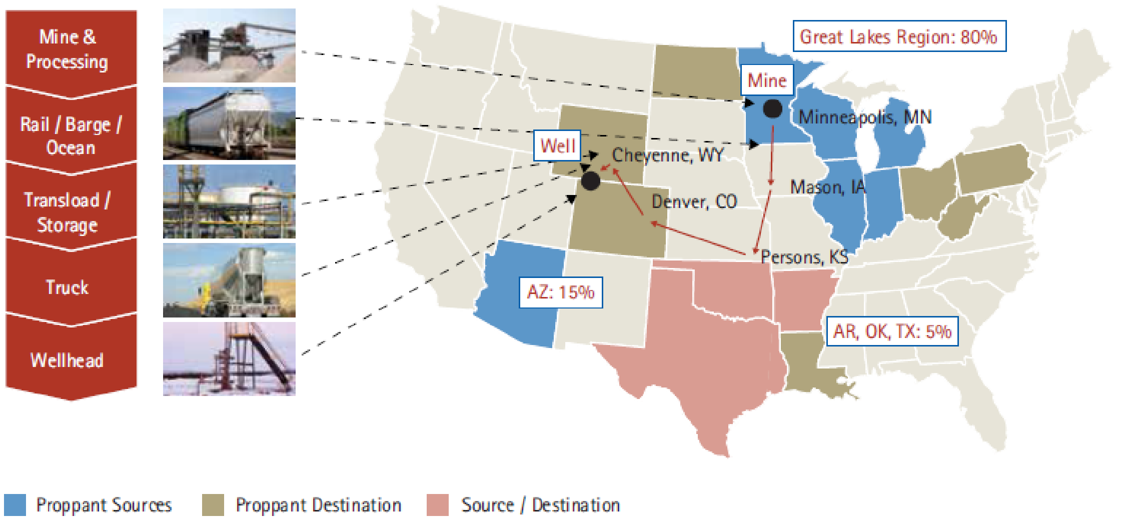


Figure 2-38 Example of supply chain frac-sand from a mine in Minnesota to a well in Wyoming. (Accenture research)

Within the US, the main production mines of frac-sand are in Midwest states like Wisconsin and Minnesota, and from there the product is transported to the producing areas, as shown in Figure 2-38.

The average purchase cost of frac-sand in the mine is between $45 and $80 per tonne, including the "mining and process". The average cost of internal logistics in the US is between $220 and $255 per tonne, including transport, storage and handling. In the case of Canada, the logistic cost for exploitations in British Columbia is between $250 and $300 per tonne, representing 80% of the total value of the sands (Canadian Mining Journal 2011). In general the contracts are 2 to 5 years long, and are private agreements between the parties, and generally confidential. The price varies according the granulometry of the sand: for example, #20 and #40 can reach $110/tonne (Minning Engineering 2012). The overall cost structure of the price of the frac-sand is shown in Figure 2-39, highlighting the importance of transportation.

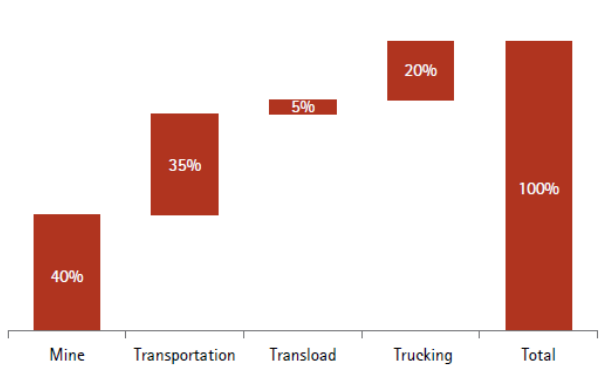


Figure 2-39 Cost structure of frac-sand in the US (Accenture Research)

One important point that should be considered is that when having a fragmented market like this, costly infrastructure may be duplicated (e.g. storage) because of competition between providers. This might not be efficient in the short run, even if it is in medium term when competition tends to correct these distortions.

As for Argentina, the importance of the transportation and logistics cost of inputs in the overall cost structure of the oil companies is high, to the point that YPF, in its presentation of progress of investments in VM in March 2014 (YPF VM Update 2014), indicated that one of the drivers to lower their well construction costs was the local sourcing of proppant, together with bulk proppant logistics, ratifying the key importance of this in their overall cost structure (Figure 2-40).

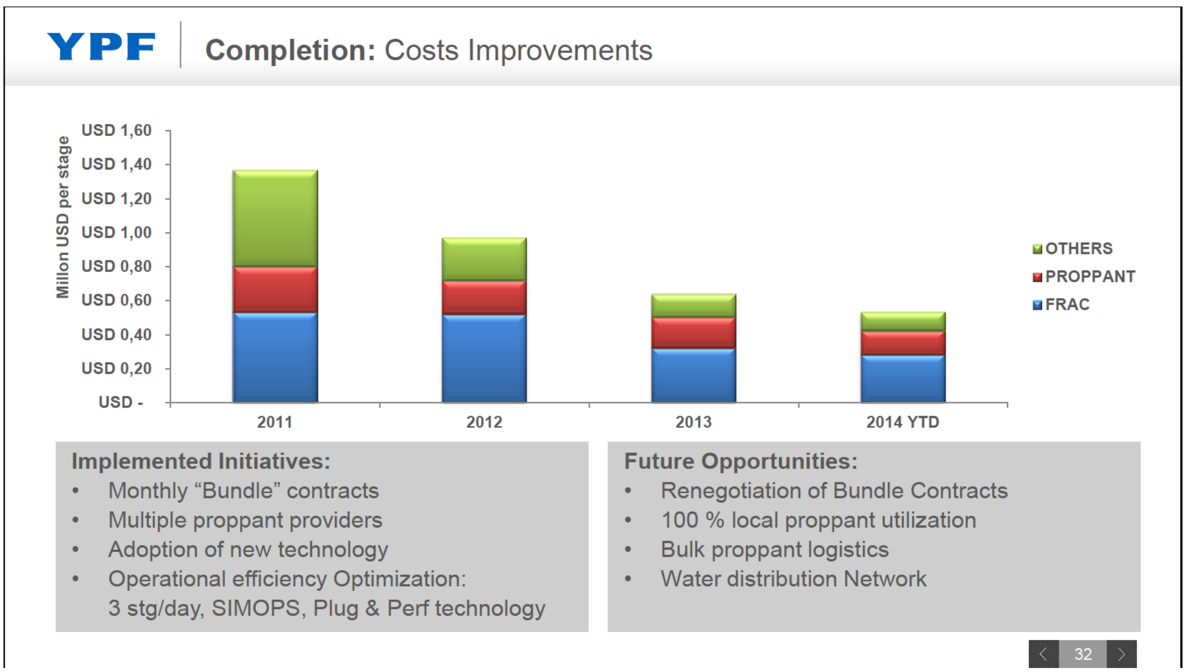


Figure 2-40 Cost improvements closely related to logistics optimization (YPF VM Update 2014)

Within the scope of this thesis, it will be assumed that any provision of frac-sand will use the East-West VM supply corridor from Bahía Blanca to Neuquén, even if the exact location of the source of the supply is not established. This corridor includes the national highways number 22 and the branch of the Ferrosur Roca railway line, used in the research case chosen in this work.

2.2.3.2. Water

Logistics for the supply of water has represented in the US one of the critical points in the development of unconventional resources. With consumption around 19 million liters per well for the stages of hydraulic fracturing and completion, water logistics may represent between 60 and 80 percent of total logistics costs. In particular a study made by Accenture (2012) states that flexibility is the key characteristic required in the water transportation management model, making then road transport the most common choice for most environments. Water pipeline and sometimes rail are used effective for long-distance or point-to-point movements, but the final distribution to the well pads in the US is almost exclusively managed via road transport (Accenture 2012). As was described before, the demand for water has high peaks during some stages of the well construction, so is the transportation demand associated, requiring up to 300 truck movements per day in large operations, causing on-site congestion, affecting operations teams and local residents, and presenting some unique challenges for the operator.

In the case of some exploitations in the US that are immersed in suburban populations, like for example in Pennsylvania (Figure 2-41), many solutions that appear to be optimal in technical terms (e.g. direct pipelines between source of water and the wells) are impractical, requiring then more expensive transport solutions like trucks.

The same Accenture study mentions: “Improved transport planning processes and systems can reduce the number of truck moves, while telematics systems can provide real-time visibility of truck movements and driver performance, supporting reduction in wait times, less congestion and better driver HSSE compliance,” proving that understanding the system’s behavior in the planning stage is required to perform a more efficient operation.

Usually the same hydro-fractures contractors are in charge of the supply of water, because of the stringent environmental regulations and the high liability associated.

Figure 2-41 Example proximity of an unconventional well with suburban towns of Pennsylvania, USA (city-data.com)

Regarding produced water (flowback), the industry trend in recent years is to reuse it in the following drilling wells, helping with two problems: lowering the requirement of new water and avoiding having to treat and dispose of this used water that has high salinity and hazardous components for the environment. Clearly this reuse requires new wells being drilled at the same time, together with specific infrastructure to transport or store the produced water from the classifiers at the producing wellhead to the new drilling areas. The logistic challenge involves fine-tuning the timing of the storage and transportation of water for reuse to provide the water at the right time (Accenture 2012). For water that is not reused, there are different options for treatment or disposal according to the specific regulations in each region.

The water logistics management is one of the key points to achieve efficient shale operations, so many operators in the US put special emphasis on developing specific logistic models to define the guidelines for the management of water transportation.

2.2.3.3. Other inputs

Besides water and proppant agent, other materials and equipment are required to be transported to the wellhead for shale exploitations, even if in smaller quantities. From the list provided by Tolliver (2014) in Table 2-14, the followings are identified as main materials: gravel, drilling mud, cement and pipes. It is clear that the values in this table are only approximate—in fact "truck trips" is not a very precise measuring unit—and depends on the characteristics of the geological formations and operational procedures. However it provides an order of magnitude of the relative importance of each of the inputs in logistic terms.

Table 2-14 Drilling related truck movements per well in Bakken (Author with data from Tolliver 2014)

Input or Product	Loaded trucks trips	Type
Water (Fresh)	450	Material
Water (Waste)	225	Material
Frac Tanks	115	Equipment
Sand	100	Material
Scoria/Gravel	80	Material
Rig Equipment	65	Equipment
Drilling Mud	50	Material
Cement	20	Material
Pipes	15	Material
Other	30	Material/Equipment

Even if the volumes of these additional inputs are considerably lower than those required for water and sand, they must be taken into account when analyzing the local impact of shale exploitations. In fact the actual impact changes by shale plays depending on the distance from the production point; in the case of VM, for example, some of them are produced in the Metropolitan Area of Buenos Aires, over 1200 km away.

In the US, in general the same suppliers are responsible for the logistics of these additional inputs deciding between different transportation, storage and distribution options.

As shown in Figure 2-38, a lot of equipment is required for shale operations, particularly necessary for the hydraulic fracture. In terms of quantity, the mains ones are frac tanks and pump trucks. The first are basically buffers to contain water and supply the wellhead when needed, while the latter are large pumps mounted on trucks to produce the pressure required for the hydraulic fracturing.

Once the rig and drilling equipment is deployed in the field (for example in VM) it keep moving between wells, producing an impact on local transport infrastructure, but in general is not transported long distance, therefore not producing a major regional impact. At the same time it is interesting that, when making a detailed study of road deterioration, these types of trucks often generate higher marginal damage to pavements, because of their axle loads distributions, special configurations or even higher loads per axle than usual (UGTPI 2014).

2.2.4. IMPACT ON TRANSPORTATION SYSTEM OF THE SPILLOVER EFFECT ON OTHER INDUSTRIES DUE TO SHALE DEVELOPMENT

A report written by PriceWaterhouseCoopers (PWC) in 2013 called: "Shale energy: A potential game-changer Implications for the US transportation & logistics industry" highlights that besides the logical growth of the logistics related to the oil sector, there is also a secondary effect produced by the spillover effect on the rest of the economy. This report states: "Shale energy is also having a major effect on the chemicals and manufacturing industries in this country, with clear ramifications for transportation and logistics companies. This new source of abundant, low-cost energy is proving to be a significant incentive for chemical producers and manufacturers to shorten their supply chain and bring production facilities back to the United States. A revived manufacturing sector would increase the need for rail and trucking to move more products domestically and for shipping exports abroad."

As mentioned in the previous sections, a decrease in the price of gas that promotes energy-intensive industries creates a whole new perspective for regional economic development. Particularly in Argentina this enhancement could be in areas such as Bahia Blanca, Buenos Aires and Santa Fe, where there are petrochemical industries that could increase and diversify production. Also aluminum (in Puerto Madryn, Chubut) and steel industries (in northern Buenos Aires) could be drivers of economic growth. This secondary effect on transport infrastructure is outside the scope of this thesis, but it is important to mention it and to understand the whole outlook.

2.3. FINDINGS AND INITIAL CONCLUSIONS

Throughout this chapter we first described the background of shale energy, starting from the basics and analyzing the US experience in the first decades of the twenty-first century. After describing the history and the current structure of the Argentine oil and gas sector, the perspective for the potential development of the shale resources in Argentina was analyzed.

Then we proceeded with the description of transport and logistic system related to shale developments, first from an analysis of the infrastructure requirements and then by presenting the current situation of the system to supply VM.

The first conclusion to be emphasized at this point is that there is definitively an established close link between energy development and transport infrastructure. The history of Argentine energy sector demonstrated over time, and the recent experience of the shale boom in the US confirmed it. In particular, shale developments require major transport infrastructure associated with the transportation of inputs, which can generate impacts on local and regional levels. Within these inputs, it was noted that water logistics produces a local impact, due to the extremely high volume on short-distance trips, while the frac-sand logistics and to a lesser extent other industrial inputs logistics, produce a regional effect by the much greater transport distance and considerable volume. This infrastructure capacity need is closely linked to achieving economically efficient operations by reducing costs, and that is why this issue is a pillar of YPF next steps in the process to lower their costs (YPF VM Update 2014). Given this situation, it is clear that new transportation infrastructure systems are necessary and therefore it is appropriate to study viable forms for planning its development, like the method developed in this thesis. In this way, next chapter extends the analysis to study the interrelationships between these systems and the institutional actors that ultimately affect the future development of infrastructure and consequently the exploitation of shale resources.

Chapter 3. THE INTERACTIONS BETWEEN THE ACTORS INVOLVED IN THE INFRASTRUCTURE DEVELOPMENT FOR VM

This chapter describes the interactions between the actors involved within the oil industry and transportation sectors in relation with the development of efficient infrastructure. This chapter will focus on evaluating these interactions and include conclusions that will serve when developing the methodology in Chapter 4.

3.1. BACKGROUND ON CLIOS SYSTEM REPRESENTATION STAGE

As was mentioned in the opening chapter of this thesis, the CLIOS Process is an organizing mechanism for understanding a CLIOS System's underlying structure and behavior. The Representation stage is diagrammatic in nature and the motivation is to convey the structural relationships and direction of influence between the components within a CLIOS system and subsystems (Sussman 2009).

"Nested complexity" is a primary characteristic of CLIOS systems and it relates to the interaction of the physical domain that is being affected by a complex organizational and policymaking system. These connections between the physical domain and institutional sphere are key components of the CLIOS System Representation.

3.2. CLIOS SYSTEM REPRESENTATION DIAGRAM

We will use the Representation stage to understand the complete CLIOS System of the infrastructure development in Argentina related to shale energy projects by examining the structures and behaviors of the physical subsystems and institutional sphere, and the interactions between them.

Figure 3-1 is a high-level diagrammatical representation that describes the interaction between different subsystems and institutional actors. Within the physical domain, the VM shale energy production system creates the need for transportation capacity and services that the transportation and logistics system provides. Both of these systems benefit from the interaction. The first system is controlled by oil and gas producers (both YPF and others) and the second by the transportation and logistics companies. Since YPF is partially owned by the national and provincial governments, there is a special interaction with them, which is different than the interaction between the governments and other Oil and Gas (O&G) producers. These interactions are described in Section 3.3.

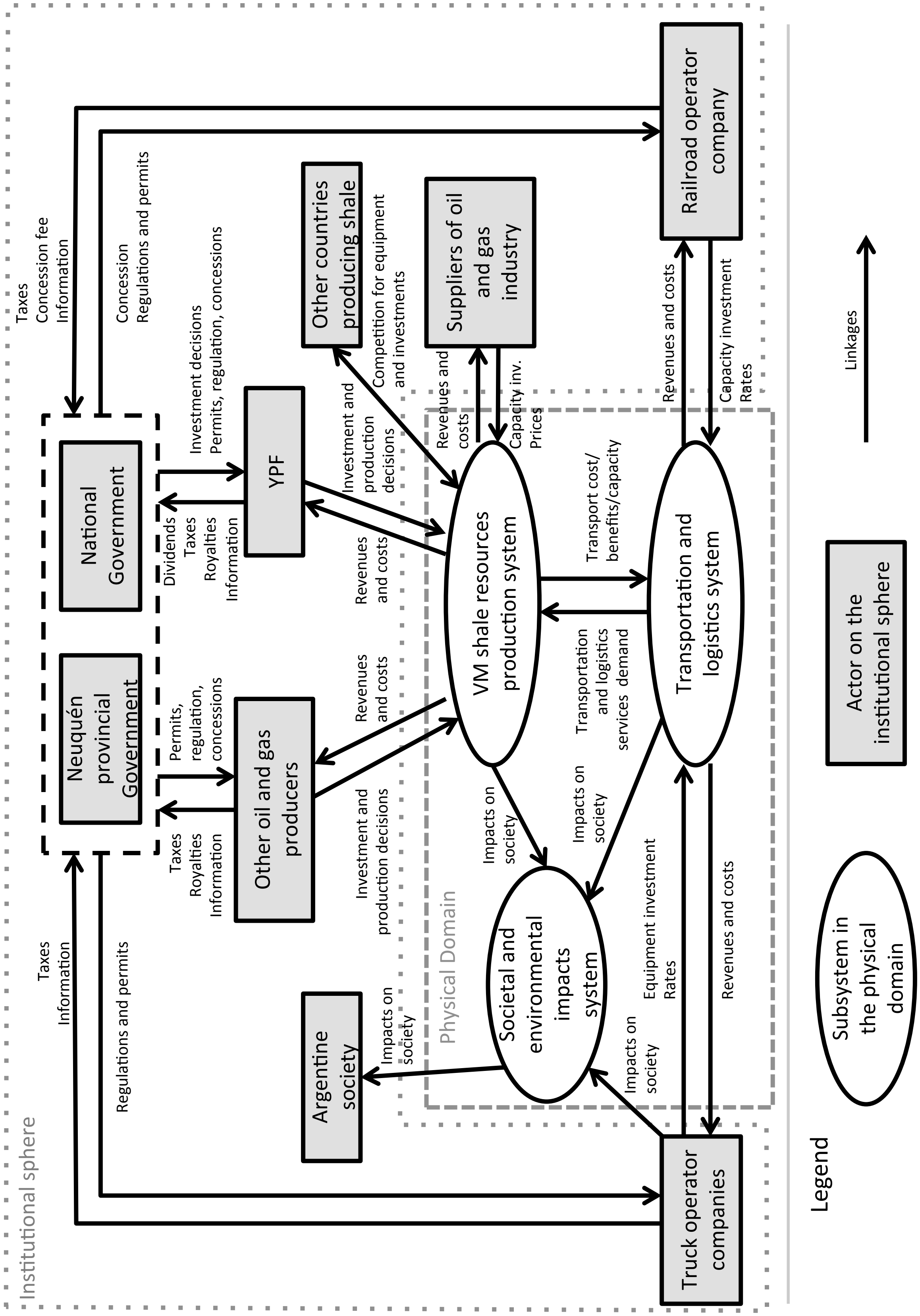


Figure 3-1 CLIOS representation (Author)

The two systems defined: VM shale resources production system and the transportation and logistics systems, were extensively described in Chapter 2 when the characteristics of each one were presented, as well as their historical evolution and physical interaction. In the next sections, the institutional sphere is explained and the interactions in the CLIOS Representation are presented.

3.3. INSTITUTIONAL ACTORS AND THEIR INTERACTIONS

The goal of this section is to describe the main institutional actors in Argentina related to the transportation of inputs to supply VM and discuss how they interact in the development of the infrastructure or the operation of the existing system. These main actors are presented in Figure 3-1 and include railroad companies, truck operator companies, YPF, other O&G producers, suppliers and governments, both national and provincial.

YPF is the leading actor in the development of VM. After its nationalization and with the leadership of Mr. Miguel Galuccio, the company took a very different direction; YPF had pulled ahead and increased hydrocarbon production in Argentina with particular emphasis on VM. At the same time, YPF understands that to succeed in the shale development, it need to achieve efficient operations, in which transportation and logistics of supplies represents a key point in this process (YPF VM Update 2014).

YPF's relationship with the national and provincial government is complex, because on one hand, these two own a portion of the shares of YPF (for which they receive dividends), but yet they are responsible for regulating, controlling and generating exploration and exploitation permits. At the same time YPF defines itself as a mix-company (like Petrobras in Brazil) that is not state-owned in the sense that it is not governed by rules applying for state-companies and is committed to producing profits for its shareholders. At the same time YPF, at this early stage of development, is making decisions in much of the supply chain, having an important role in the planning of the required logistic infrastructure.

The rest of the O&G producers have a more traditional relationship with the national and provincial government: they bid for concessions and, if they win, they pay an initial fee and a royalty of 12% of the production (in addition to the income and other taxes). On the other side, the governments are in charge of their regulation on environmental, safety, and other subjects.

Suppliers are complementary actors at this point, satisfying the demand for inputs and in some cases handling the logistics. This distinction is not entirely clear, and perhaps is one of the main differences between shale exploitations in the US and Argentina. If YPF vertically integrates its supply chain, probably it will have more relative weight in the sector and suppliers will not make logistics and transportation decisions. In the US it is usually the opposite, where suppliers are responsible for the supply of inputs to the well and oil producers focus on their core business. Probably VM, in the medium run, will be in an intermediate situation in which some suppliers will be in charge of their logistics, and in other cases it will be YPF who manages it, probably depending on the relative costs. In any case, it seems reasonable to think that producers are the ones more interested in lowering the transportation costs, and probably they will have sufficient decision power to delineate or incentivize efficient logistics strategies to the complete supply chain.

In terms of governments, the two actors (national and provincial) have different responsibilities and receive different revenues. As mentioned in Section 2.1.3.1, by the federal conception of Argentina, the provinces are the owners of the natural resources so they ultimately take the responsibilities for creating the concession areas and collecting the associated royalties. In the same way, the provinces are responsible for the environmental, safety and other regulations that the companies must comply with.

The national government, in places where concessions are provincial[19], maintains the role of controller, receiving information, but not directly regulating the industry activity. At the same time, like any other sector, the companies have to pay their taxes (including corporate income tax) and comply with all the regulation for commercial activities.

In the case of the rail operator, Ferrosur Roca has a concession that started in 1993 and will end in 2023 that, as mentioned previously, was issued by the national government in return for an annual fee. However, the Argentine Congress approved on April 15, 2015 a law[20] that allows Open Access to the railroad infrastructure (including the private concessions), allowing other operators to eventually compete with Ferrosur Roca on the Roca line in the short term. In fact, this law foresees a logical renegotiation of the Ferrosur Roca concession. Actually, the original Ferrosur Roca concession contract theoretically allowed the operator to charge a toll to other operators who would eventually use the infrastructure, so the implications are still uncertain.

[19] Because in offshore exploitations, for example, the national government is the owner of the resources and is in charge of issuing the concession and permits.
[20] Still no official number of law because of its recent enactment.

In this new Open Access regulation, the government will be the Infrastructure Manager, charging operators for the use of the tracks. The debate about how to allocate capacity and how to charge for this infrastructure is open and complex; Peña-Alcaraz (2015) developed a mechanism to analyze the capacity pricing and allocation for shared railway systems.

Besides this, like any commercial enterprise, the rail operator pay taxes and is subjected to general and specific regulations. The national government is the owner of the tracks and some of the rolling stock[21], so it would be reasonable to think that before any major infrastructure investment (e.g. rehabilitation of tracks or extensions), the national government would be a big player in the decision, at least in the current organizational structure. In any case, the author argues that the legal framework of the railroad sector is certainly not appropriate to achieve the necessary capacity investments for VM. The private operator does not have a proper investment horizon (eight years is too short in relation to the magnitude of the investment required), medium term state railway policy is completely unclear and there are probably going to be changes in the short term. In the context of this thesis, any of the strategic alternatives analyzed for VM that include railroad investments will need a reevaluation of the institutional structure of the sector.

Regarding the trucking companies, the industry is much more fragmented due to the nature of the business. Both governments regulate the activity, and oil companies or suppliers contract the trucking companies on short or medium term contracts. This sector is mainly driven by competition, but the big point is that it is not clear if the trucking rates include the actual deterioration of the infrastructure they cause. In comparative terms, since the rail operator is also responsible for performing maintenance on tracks, the rail rates will includes the costs associated with the infrastructure deterioration. In the case of roads, since the use of national and provincial networks is virtually free[22], the payment for the use of infrastructure is only given by indirect taxation (such as annual registration fees or similar), that are not related to the actual deterioration predicted. In this sense, it is not clear if the trucking rates, which in a competitive market tends to be equal to the marginal cost of the operator, actually includes these infrastructure cost components; a priori it seems that does not. So, this deterioration that is not paid by the users is ultimately a direct impact on society, like accidents and pollution externalities for example. Against

[21] In the 1993 concession, the existing rolling stock was included in the transfer to the private operator but it is still owned by the national government. The new rolling stock acquired during the concession by Ferrosur Roca is privately owned.

[22] In some highways, the DNV implemented a concession system with tolls but in general the amount paid did not represent the actual deterioration of the infrastructure but at most part of it.

this, there is a debate about the implementation of systems for charging road use according to its use, implementing widespread GPS technology or similar. The state of Oregon in 2013 has initiated a process of implementing this system, and on the website of the Oregon Department of Transportation says: "The 2013 Oregon Legislatures passed Senate Bill 810, the first legislation in the United States to establish a road usage charge system for transportation funding. The bill authorizes the Oregon Department of Transportation to set up a mileage collection system for 5,000 cars and light commercial vehicles beginning July 1, 2015. For those who volunteer to participate, the Road Usage Charge Program, also known as OReGO will assess a charge of 1.5 cents per mile and issue a gas tax credit as warranted. This will not be another pilot program but rather the start of an alternate method of generating fuel tax from specific vehicles to pay for Oregon highways." This is still in the pilot stage and there is great public debate, especially related to privacy issues. However, the author considers interesting that new technologies could help avoid these "imperfections" in the charging infrastructure use. The analysis of this problem of distortion between modes will be extended in Chapter 4.

Finally other institutional actors are labor unions that had strong influence in Argentina over its history, especially the ones related to the trucking and oil industry. But, even if they are relevant in the general context, the author considers that their interaction is mainly inside their own industries: for example for the trucking companies, the relationship with the union is critical, but does not seem to have much interference on the linkages presented in the CLIOS Representation of Figure 3-1, and that is why they were not represented as a separate entity.

3.4. INITIAL BUNDLES OF STRATEGIC ALTERNATIVES

To achieve the transportation of the required input--water, sand, construction material equipment, pipes, etc.--to VM through the East-West supply corridor selected as the research case, there are several alternatives possible. In Figure 3-2 the bundles of strategic alternatives are presented following a 3-level classification. The first level is the transportation mode; the second is how the infrastructure capital investments are funded and the third is related to the source of funding for maintenance.

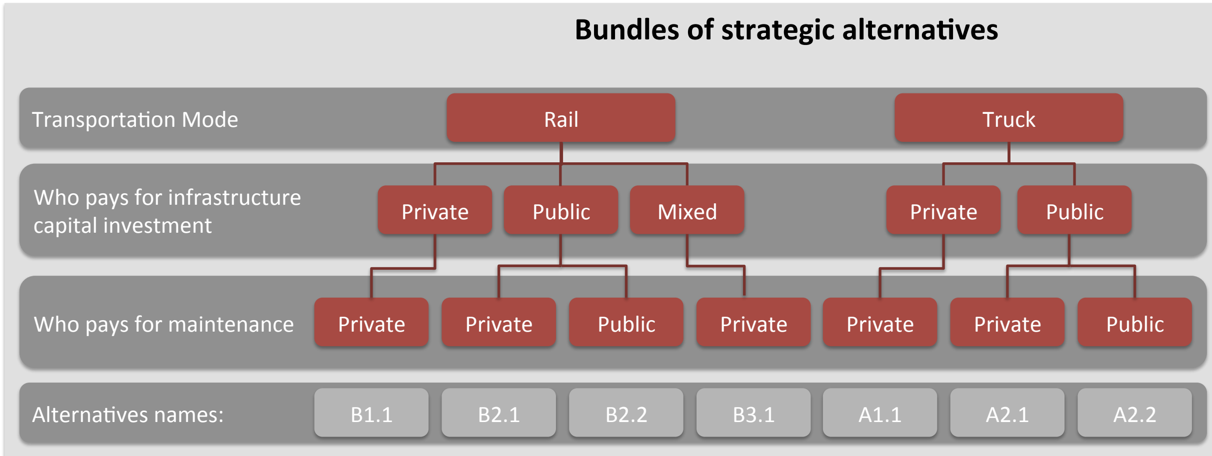


Figure 3-2 Bundles of strategic alternatives for developing logistics infrastructure in the East-West VM supply corridor —Research case—(Author)

The different actors in the institutional sphere have different levels of influence in each of the bundles of strategic alternatives, so that incentives may not be aligned or balanced.

These alternatives differ substantially in the conception of how the necessary infrastructure should be planned, financed and executed. The reason for these differences is going to be presented in Section 4.1, but conceptually here we have a ”monopoly" in the use of the infrastructure, in which a single (or few) oil company benefits from the lower cost of using more efficient transportation alternatives that require capital investments. Then: is it right that the Public Sector pays for an infrastructure that will be primarily used by one user in a quite profitable business (oil and gas)? The author considers that the answer to this question is not trivial, at least using the traditional Benefit-Cost Analysis (BCA) techniques, in which in general the beneficiaries are dispersed.

Both answers to this question (yes or no) have arguments that are going to be detailed in Section 4.1, as part of the introduction to the methodology.

However this can lead to the issue previously presented of the incorrect monetization of some costs in certain modes (such as the deterioration of the highways or the environmental damage produced by trucks) that can lead to a “best” solution from the point of view of a private company that is sub-optimal for society as a whole, requiring more resources or generating high externalities that were not monetized and translated to the private operator, and are paid for by the rest of the society.

At the same time, there could be benefits of using some transportation alternatives over others that are not quantifiable in monetary terms and, since the role of the government is to ensure the benefit of the whole society, this may lead us to think that the public should invest in this infrastructure or incentivize its use. At the same time, the oil companies themselves may argue that by paying their taxes, ultimately they are paying for these public works.

This is even more complicated when there are imbalances between modes: following the example of road deterioration; if the railroad rates includes the infrastructure capital cost and the trucking rates does not (or is very indirect), then there is an unfair competition between modes and the decision of the private operator may lead to a suboptimal solution. These bundles of strategic alternatives of Figure 3-2 will be applied for the research case on the East-West VM supply corridor.

3.5. FINDINGS AND INITIALS CONCLUSIONS

This chapter introduced the CLIOS Representation based on the system description made in Chapter 2 for the shale energy and for the logistic infrastructure related to VM. Finally, it introduced some of the actors in the institutional sphere and discussed their influence over the strategic alternatives.

While it would be premature to draw conclusions based on this initial system representation, there are some initial findings that stand out.

- The shale oil and shale gas exploitations require large and sustained (over time) investment levels, to ensure the "drilling density" to even maintain the level of production which makes this activity very sensitive to changes in oil prices.
- VM has shown favorable physical and geological characteristics. The first results of the pilot projects led by YPF in a joint venture with other IOCs were promising, but there is still a very cautious investor environment awaiting the outcome of the political changes of 2015, when a new president is elected.
- The sharp decline in oil prices since mid-2014 brought some doubts about the economic viability of shale energy since, even if there is not an official value, some observers argue that the break-even price for VM is around $75 per barrel, with an international price around $50. But, in Argentina because of the price control of the domestic oil, in the beginning of 2015 the price was established at about $80, making Argentine consumers subsidize the development of VM. Interestingly, it is exactly the opposite of what happened in the last decade, with high international prices and artificially low regulated domestic prices, with differences of up to $100 per barrel when the international price was trading around $140 and the local $40. In any case, these low oil prices are pushing operators to

seek efficiencies, and logistics appears as the key point (YPF Investor Presentation–March 2015).

- The market for natural gas experienced a similar process: the Argentine domestic price went from $ 2.5 to $ 7.5 per billion of BTU in 2012, a value that is for now fixed for the producers, not fluctuating with the international market.
- The virtual "high" internal price might not be stable in the medium term, because if international oil prices continue below $50, the industrial productivity of the country could be affected by the high energy cost in comparison with other regional producers (e.g. Brazil). In any case, this international context is encouraging more efficient operations. YPF is leading this tendency, and focuses its attention on lowering the logistics costs of inputs (YPF VM Update 2014).
- The same technology that makes this shale exploitation technically possible is counterbalanced by the high demand for transport services. Depending on the inputs and the locations of the source of production, transport can generate a localized (e.g. water logistics) or a regional impact (e.g. sand logistics).
- A priori, there are several opportunities on which the VM operation can achieve efficiencies in their logistics costs, one of which is the research case of the East-West VM supply corridor. However to achieve these operational efficiencies, capital investment in infrastructure is required.
- The spare capacity on the outbound logistics due to the decrease in the conventional oil and gas production in the last decade would make it possible to transport the products of the first phase of VM without making large investments. The difference between shale and conventional is the form of exploitation, but not the product itself, which has the same transportation characteristics, in opposition to the Canadian oil sands (Carlson 2014), for example. In addition, as was mentioned in Section 2.1.3.4, the institutional composition of the midstream sector of the O&G industry in Argentina is market-oriented and is consolidated, so probably it will be able to quickly adapt to future market needs.

The fundamental definition of the infrastructure requirement for VM development has been established and the bundles of strategic alternatives were presented, but it is not clear how to plan, finance and develop new logistic infrastructure for making the VM operation more efficient in this context of mixed participation of private companies, national and provincial government. The following chapter will address this specific problem with the development of a methodology that contains the different ways to analyze infrastructure alternatives.

Chapter 4. A METHODOLOGY FOR SIMULTANEOUS ECONOMIC-FINANCIAL ANALYSIS TO EVALUATE INFRASTRUCTURE ALTERNATIVES.

Having studied the foundations of the energy and the transportation and logistics sectors, and analyzed what happens in the US, this chapter develops a methodology for evaluating investment infrastructure alternatives taking into account the interests and interactions between the different actors. This chapter will use the research case of the East-West VM supply corridor as an example case.

4.1. NEED FOR A NEW METHODOLOGY

As was previously introduced in Section 3.4, the requirement of investment in transportation and logistic infrastructure is an intrinsic characteristic of the shale energy exploitations. These infrastructures are by nature expensive and require a high level of analysis and planning, especially when public funds are committed.

In order to evaluate transportation alternatives, the first traditional approach is to perform an economic evaluation through the tools defined in the Benefit-Cost Analysis (BCA) by computing in each case the total economic cost, including its externalities (environmental, congestion, etc.). This analysis determines which alternative is the most economically efficient for the society, regardless of who pays each cost, and we could think it would be the one selected by a "benevolent dictator" who "owns" all the resources in a totally controlled economy.

It is important to notice that in this case we are trying to compare between alternatives (not to evaluate a particular infrastructure project), so the economic evaluation is an objective measure of the social economic resources consumed to perform this transportation, being then the results of adding all the economic costs involved.

However, BCA do not distinguish which actor pays each cost. For example in a project evaluation of a capacity increase of a highway[23] segment, the beneficiaries are all the users of the road and also all consumers of products whose prices decrease by lower transportation cost. So, if the highway is being paid for with public funds and the beneficiaries are the same population, if the project has

[23] The highway segment was used as an example since is a public infrastructure with in general free access to users.

more economic benefits than cost, then this is a good allocation of resources and the government should make the investment.

But for VM, we have a ”monopoly" in the use of the infrastructure, in which a single (or few) oil company benefits from the lower cost achieved by the construction of this infrastructure. Then a crucial question arises: **is it right that the Public Sector pays for this infrastructure that will be primarily used by one user in a quite profitable business (O&G)?** Regarding this idea, two opposite positions are stated in Table 4-1.

Table 4-1 "Yes" and "No" basis statements for public investment of new infrastructure (Author)

YES: public sector should pay	NO: companies should pay
The use of an efficient alternative benefits the whole society, and the public sector must ensure it, as guardian of the common good.	*The reduction of operating costs due to the use of more efficient technologies (i.e. railroad vs. trucking) generates additional profit for the companies that could be used to build infrastructure.*
Oil companies pay taxes, which include the use of public infrastructure. In fact, a reduction of operating costs will increase the income tax paid by the companies (keeping all else constant).	*There should be a limit to the use of free public infrastructure "included" in the general taxes paid by companies.*
This infrastructure could create an induced demand and economic growth due to reduction of transportation costs for other sectors of the economy.	*Oil companies should internalize infrastructure costs needed for their operation to force them to make efficient decisions.*
…	*…*

So, even if an optimal economic alternative can be identified in a straightforward BCA analysis, **it is not clear who should pay for the infrastructure**. As we will see in the following sections, this question is not trivial because the real-world taxation system and incentive alignments are not perfect. Changes in the answer of "who pays?" for the infrastructure could eventually change the incentives of the stakeholders, moving us away from the optimal solution. As Grigg (2010) states:

"Infrastructure is not just a public good or a private good: infrastructure systems serve both public and private purposes, and it will always be difficult to draw a fine line between services that can be financed through consumer choice and those that require government mandates and subsidies. This juxtaposition presents a challenge to the political and economic systems."

The same companies have in many cases two perspectives on this problem: on one hand, the operators have a commitment to produce oil and gas in the most efficient way by reducing their costs and hence maximizing their profit. But at the same time, they know that their decisions have a direct impact on the society and that they should take into account the social, environmental and regional economic perspective when analyzing logistic alternatives of this size, in order to construct a sustainable solution. And this is not only from the point of view of social responsibility, is a matter of reality: for example if a large operation of a company (as the ones presented for VM) heavily deteriorate a highway, not only the same residents will complain, but their own operating cost will increase due to this deterioration. An alternative that is not sustainable in the long term due to complaints from residents or externalities is ultimately not a good decision for the company either, but this may not be obvious at first if incorrect incentives are in place.

Kurowski et al. (2011) say the reason companies should be "interested in economic analysis is that the project must *live* in the environment in which it is to be created—it must be able to prosper and grow. A project's compatibility with its wider domain is conducive to project success."

In relation with these external impacts, because of the size of this operation, it is not possible to argue that it will create only marginal incremental externalities (i.e. traffic generated), so a specific analysis is required to understand the comprehensive situation.

After identifying the most economically efficient alternative, the analysis should consider the position of the private companies by performing a financial assessment of each alternative. This secondary analysis will provide very useful information for the decision maker: to know if the incentives of the companies are in line to reach the most efficient alternative for the society, without the intervention of the government.

In order to clarify the need for this secondary financial assessment, a particular example is detailed. In the case of alternatives that require very expensive infrastructure (i.e. new railway lines), the particular conditions for the private companies could make the capital–intense alternatives uncompetitive even if they could be the most economically efficient in the long term. This could be caused by the cost of private capital that could be very high if the perceived risk of the investment is high, due to the uncertainty. For example if the private investor believes that the legal framework is weak and therefore requires high internal rates of return (or shorter repayment periods), the project could be more expensive for private pockets than alternatives that require less initial capital (e.g. trucking alternatives). In this case, the incentives of the private companies are not aligned with those of society as a whole, and to reach the optimal alternative, a government intervention is required because it is the only entity that could mitigate this perceived institutional risk and manage better uncertainty. Zerbe et al. (1994) mentioned this as a "divergence of private and social cost" that is a necessary condition to prove that a government action may improve the situation, but not a sufficient one: this will be determined by further analysis.

Having raised this idea, then the need for information is clear to move towards a process that will likely require negotiations between the public sector and private companies to reach a fair solution. In order to solve this problem in a systematic way, a methodological framework is presented in Section 4.2.

4.2. STRUCTURE OF THE SIMULTANEOUS ECONOMIC-FINANCIAL ANALYSIS MODEL (SEFAM)

This section presents the Simultaneous Economic-Financial Analysis Model (SEFAM) for the evaluation of infrastructure investments in shale energy developments.

To understand this problem and to find a solution in a systematic way, a methodology is developed to advise some actions that could help the alignment of the incentives and, at the end, conclude with the implementation of the more efficient alternative from both (private and common good) perspectives.

The comprehensive methodology of SEFAM is conceptually shown in Figure 4-1:

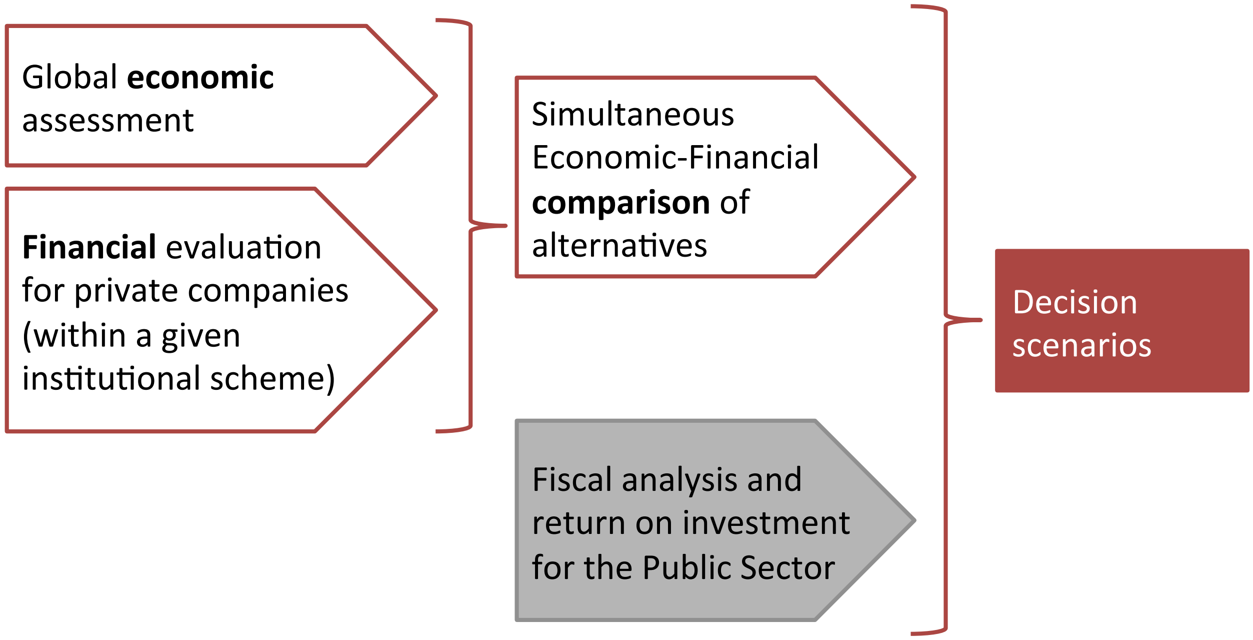


Figure 4-1 Comprehensive methodology of SEFAM (Author)

A mathematical formulation of the comparison of economic and financial alternatives is provided in Figure 4-2.

Select **i** that makes Min $\left[NPV_{Economic\ Costs_i} = \sum_{t=0}^{T} \frac{EC_t}{(1+r_{society})^t}\right]$

Select **j** that makes Min $\left[NPV_{Financial\ Costs\ for\ a\ Private\ Company_j} = \sum_{t=0}^{T} \frac{FC_t}{(1+r_{pc})^t}\right]$

If $i_{min}=j_{min}$ then the incentives for the private companies are aligned with the common good.

If $i_{min} \neq j_{min}$, government intervention is required to develop new sub–alternatives.

where:

i: alternatives evaluated in the Global Economic Assessment

j: alternatives evaluated in the Financial Evaluation of Alternatives from a Private company perspective

i_{min}: most economically efficient alternative

j_{min}: lowest cash flow cost alternative for the private company

$r_{society}$: discount rate for project evaluation from a whole society perspective

r_{pc}: discount rate for project evaluation from a private company perspective

t: years

Figure 4-2 Mathematical formulation of the comparison of economic and financial alternatives (Author)

Each of the elements of the methodology is described below:

- **Global economic assessment:** the objective is to determine the most efficient alternative to make transportation in global economic terms for the society as a whole, without considering which actor paid each cost. This means: if I am the owner of all the resources in the economy, which is the alternative that consumes fewer resources to transport a good from an origin to a destination? For doing this, the economic resources consumed to transport the inputs in each alternative are calculated. This analysis corresponds to the interests of the society, which should, in principle, be ensured by the governments.
  The basic idea is to apply the cost evaluation of the BCA noting that the quantity to be transported is not a function of transportation costs, since the amount was defined in a previous oil and gas production decision. For each alternative, the total economic cost is computed, including externalities (environmental, congestion, etc.). All costs do not include taxes or subsidies, because this global analysis considers society as a whole so that taxes would be internal transfers between actors.
  Since this is a economic cost evaluation (not a project evaluation), the "benefits" of one alternative over the other are presented as difference in costs, because ultimately all the alternatives achieve the same goal: to transport a fixed quantity of supplies to VM with different costs. The result of this phase is a discounted cost for each alternative and, therefore the definition of the most economically efficient alternative to society.
- **Financial evaluation for a private company:** the objective is to compute the actual cash flow (commercial) cost of each alternative from the perspective of the private operator, including financial (not economic) costs for the company. This analysis considers only the actual costs incurred (cash flow costs) for the transportation, so the externalities are not considered; neither is any other social cost that is not reflected in a monetary commitment for the company. These costs include taxes, since these are actual monetary expenses in the private perspective (Kurowski et al. 2011).
- **Simultaneous Economic-Financial comparison of alternatives:** after developing and computing the cost of each alternative (direct and external costs), an economic and a financial comparison are performed in order to identify the magnitude of the differences of total costs between each alternative in the perspectives of the society and the private company. This comparison results in the quantification of:
  - Economic savings: total savings due to the implementation of more efficient alternatives for the society, including externalities savings (for example reduction of accidents) along with operational efficiency savings (due to the use of a more efficient technologies, i.e. railroad).
  - Financial savings: savings of private resources for the oil companies because of lower operating costs.

- **Fiscal analysis and return on investment for the Public Sector:** once the comparison is performed and if there exists alternatives that generate significant savings for society as a whole, a new question is raised: would it be efficient for the government to invest in this infrastructure to generate those savings? And going even further: what would the cash flow of the Public Sector treasury be when the infrastructure investments and the income of royalties from VM exploitation are included?
- **Decision scenarios:** with the results of the previous analysis, some negotiation scenarios between the stakeholders could be established, for example, between private companies (i.e. YPF) and the Federal Government. So, with the comparison between alternatives and the analysis of the fiscal perspective, it is possible to develop a bundle of possible decision scenarios. These scenarios take into account the different participation of the stakeholders and their degree of involvement.

The alternatives to be analyzed are the initial bundles of strategic alternatives defined in Section 3.4, so the interactions with the actors in the institutional sphere have been included in the analysis since the beginning.

Kurowski et al. (2011) also presented this idea of economic and financial analyses under the names of "economic and commercial" (Figure 4-3) but with a different purpose; the commercial analysis is presented as the first step of the ECBA (Economic Cost/Benefit Analysis) Process to evaluate a project, but not to take specific actions to understand the incentives of the private sector. In the mentioned work, the authors made a detailed analysis of the use of shadow prices in the economic assessment together with the presentation of a discussion on market imperfections, part of which are also included in this thesis (i.e. externalities).

	Commercial	Economic
Applicability	All projects	Public- and private-sector projects—scope depending on range of impacts
Objectives	Maximize return on invested capital and/or wealth accumulation	Improve standard of living
Constraints	Existing infrastructure, legal regulations, risk tolerance	Government priorities on development, income distribution, savings rates of income groups, balance of payments situation
Parameters	Market prices	Economic prices reflecting scarcity of resources, national parameters
Resources	Investor's financial strength	National resources (labor, land, capital, mineral deposits, etc.)
Criteria	Returns on equity and investment, yield curve on debt instruments	Maximize benefits from use of national resources, equitable income distribution among contemporaries and generations

Figure 4-3 Main characteristic of Kurowski's analysis framework (Kurowski et al. 2011)

4.2.1. GLOBAL ECONOMIC ASSESSMENT

As was previously mentioned, this is the perspective of the "benevolent dictator", who owning all the resources of the economy tries to find the alternative that consumes fewer economic resources to transport a good from an origin to a destination. This analysis corresponds to the interests of the society, which should, in principle, be ensured by the governments and do not take into account which actor paid each cost. All costs do not include taxes or subsidies, because this global analysis considers society as a whole so that taxes would be internal transfers between actors.

As was mentioned in the previous section, since this is a cost evaluation (not a project evaluation), the benefits of one alternative over the other are presented as difference in costs, because ultimately all the alternatives achieve the same goal: to transport a fixed quantity of supplies to VM with different costs.

To perform this phase, the main difficulty is to identify the actual economic cost (internal and external) of each alternative and then to identify and quantify the investments needed. In order to systematize this part of the analysis, a series of steps were defined (Figure 4-4). These steps were developed for the specific case of evaluating shale energy related transportation infrastructure, but there are surely equivalent steps for the assessments of other types of infrastructure.

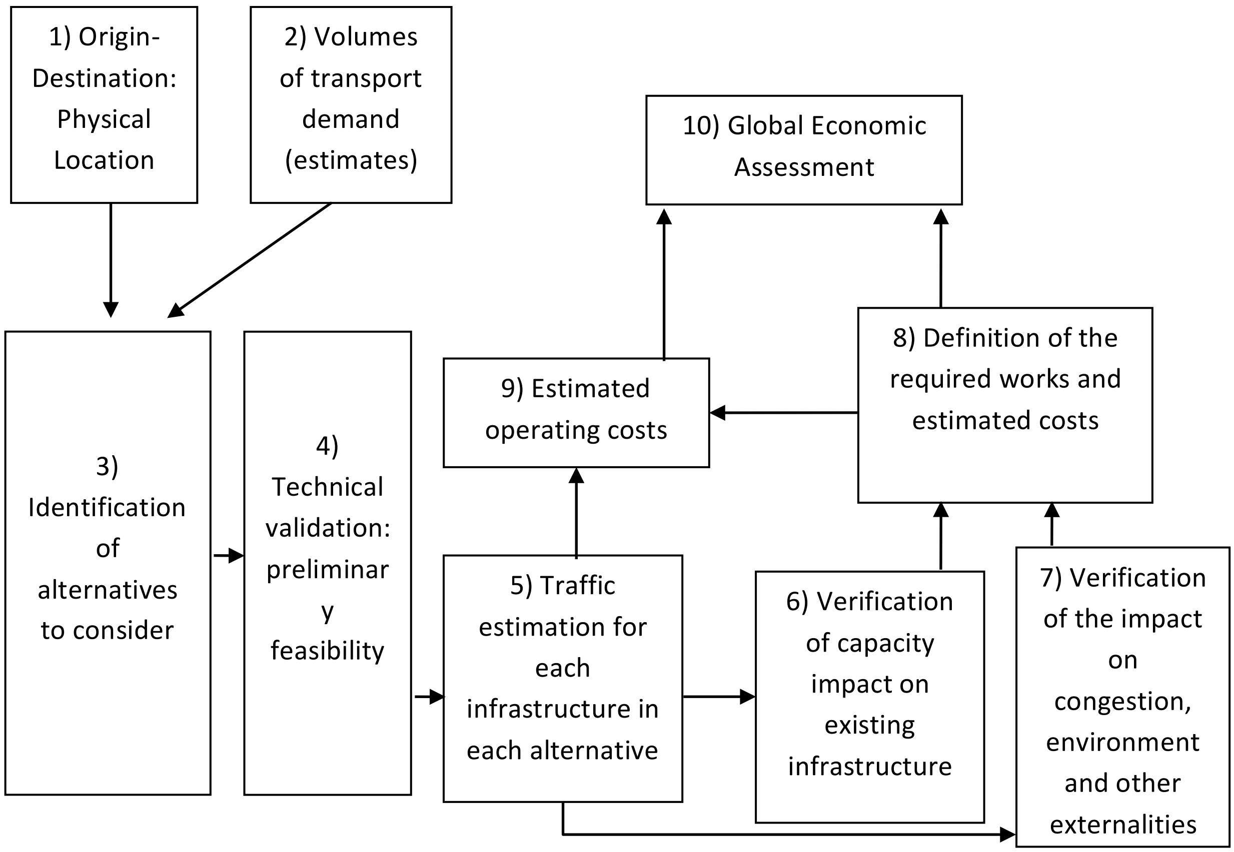


Figure 4-4 Layout steps Stage A: Global Economic Assessment (Author)

The first two steps are based on the transportation demand and the characteristics of the operation; the combinations of both measures (volume and distance) are the main drivers for transportation decisions.

From all the possible physical transportation alternatives (step 3), a subset of technically feasible alternatives is selected (step 4). For example, in a trucking alternative this step will analyze the different technically reasonable routing alternatives.

The objective of the step 5 is to quantify the traffic on each infrastructure. A particular model of traffic generation is required; in this case, this will be a function of the on-site characteristic of the exploitation.

With the traffic generated on each infrastructure in each alternative, it is possible to perform two simultaneous verifications: the capacity constraints (step 6) and the impact on congestion, environment and other externalities (step 7).

For highway infrastructure, the capacity evaluation could be performed following two perspectives: traffic and structural. In the traffic perspective, the amount of traffic before and after VM could be evaluated, along with the percentage of trucks before and after. The objective is to determine whether the operational capacity of the infrastructure was reached (i.e. the operation capacity of a two-lane highway).

At the same time, a structural analysis is performed by evaluating the number of ESAL (Equivalent Single Axle Load) produced by the new operation and to compare with the "normal" deterioration of the road under current conditions. This marginal analysis allows us to calculate and then to allocate the cost or reconstruction due to the new traffic.

For the railroad infrastructure, an evaluation of spare operational capacity of the current system is performed as verification.

Step 7 includes the evaluation of congestion and externalities. This evaluation is hard to perform in an objective way, because some values are very difficult to monetize. In this case the author proposes to evaluate three sources of externalities: congestion, accidents and greenhouse emissions. Clearly there are other sources of externalities such as environmental pollution due to particulate emission to the atmosphere (air quality) or noise pollution, but for the scope of this thesis the sources of externalities considered were those previously mentioned. The following methods are used to quantify each externality:

- The **traffic congestion** produced by each alternative is quantified by measuring the increase in travel time due to VM operation. The idea is that the additional traffic produced by VM will generate a delay to the general traffic that could be quantified by the additional travel time. The method selected was the one specified in the Highway Capacity Manual 2000 of the Transportation Research Board (HCM 2000).
- The number of additional road **accidents** (fatalities and injuries) in each alternative is a key factor for the public opinion in general, and in particular in the local communities. To quantify this externality a specific model is required to predict the additional accidents as a function of the Annual Average Daily Traffic (AADT) and the percentage of trucks. For the scope of this thesis and after the analysis of five different models available, the author decided to implement the Dell'Acqua and Russo (2010), "Accident Prediction Models for Road Networks." Since the development of a specific and calibrated accident model for the Argentine case was beyond the scope of this thesis, the author considered that the implementation of the Dell'Acqua model was the best solution available. But the author wants to explicitly emphasize that given the importance of this point, it is recommended

that the modeler use a calibrated model for the reality analyzed when implementing the SEFAM model in a real decision analysis.

- The **greenhouse emission** externality is quantified by measuring the CO_2 generated per liter of fuel consumed by each alternative, as a function of technical characteristics of the equipment (combustion engine, travelling speed, etc.). For computing this, some official coefficients from data of the Argentine Secretary of Energy (ASoE) are used.

After identifying the externalities produced, in Step 8 all the variables are monetized into economic values, with the following considerations:

- **Traffic congestion:** for the value of time, we used the statistics of the DNV (2012).
- **Accidents:** the value of a life was computed as a function of GDP, following the paper of McMahon and Dahdah (2008).
- **Greenhouse emissions:** the valuation of greenhouse emissions is very complex, so for the scope of this thesis, the economic value considered is the historic price of carbon bonds.
- **Cost of reconstruction or construction of new infrastructure:** the author used recent values of public work procurement of railways and highways construction in Argentina.

Then, in Step 9 the operating costs are computed. In the case of trucking alternatives, the author used the data provided by DNV and for the case of railway an ad-hoc cost analysis is prepared using international standard values.

Finally, all these economic values are included in a projected cash flow and the total discounted cost over the 15 years of the project is computed. This time period was selected considering that, even the VM project is much longer, 15 years is the time period that a private company will use to evaluate a project like this with uncertainty respect to the variation in price and availability of shale resources.

4.2.2. FINANCIAL EVALUATION OF ALTERNATIVES FROM A PRIVATE COMPANY PERSPECTIVE

Under this perspective we look to find the alternatives with lower financial cost (also called commercial) to transport a good from an origin to a destination. The objective of the financial evaluation is to identify the actual cash flow for the companies for each defined alternative. In this case the author considered only the cost that the companies actually incurred for transportation of inputs, without taking into account any opportunity cost or external cost, and considering subsidies and taxes since are as was described in Section 4.2.

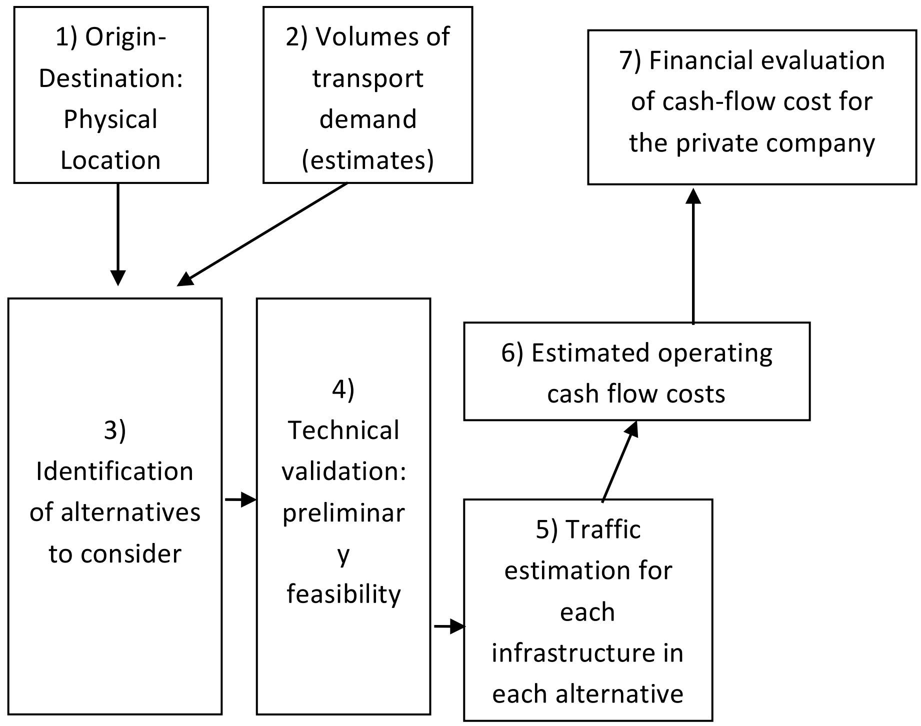


Figure 4-5 Layout steps Stage B: Financial Evaluation for YPF (Author)

The first 5 steps are the same as the Global Economic Assessment; steps 6 and 7 are different. The step 6 includes an estimation of the operating cash flow cost using the methodology of the National Highway Administration of Argentina. These values are a measure of the financial cost of operation of trucks in the highway network of Argentina. For the rail alternatives, to estimate the financial cost for the private company we add taxes to the economic costs identified in Section 4.2.1.

4.2.3. SIMULTANEOUS ECONOMIC-FINANCIAL COMPARISON OF ALTERNATIVES

A comparison based on **total economic discounted cost** per tonne was used to compare different alternatives in terms of their total cost for the society. With all these results, the **most efficient alternative** is determined and a comparison of operational efficiencies and externality savings is performed.

Then, a financial evaluation between alternatives is performed following a similar procedure as the Economic Assessment: computing the present value of the transportation cost by alternative, except that in this case these are financial costs for the company.

The financial comparison includes who pays for each cost, so all the initial bundles of strategic alternatives presented in Section 3.4 have different results.

Both comparisons arrive at a final value of savings in economic (for the society as a whole) and financial terms (for the companies).

Continuing with the preliminary example presented in Section 4.1, the comparison could conclude that a 100% railroad alternative is the most efficient alternative for the society as a whole but it is not the more convenient alternative for the private sector, if it is required to make all the investment by itself. The verification of this example is provided in the Section 4.3 with the application of SEFAM to the research case of VM. Then, the solution will require a public support (i.e. capital investment or financing) in order to make the socially optimal alternative also the best for the private company. If this public support does not exist, then a completely private funded railroad alternative would generate a cash flow cost greater than the actual trucking cost (caused for example by an expensive capital cost due to the risk perceived), not providing any incentive for the private sector to invest in the infrastructure and producing an overall sub-efficient solution for the society.

4.2.4. Fiscal analysis and return of investment for the Public Sector

The different results open a variety of intermediate solutions regarding the participation of public and private investment. In order to analyze different negotiation scenarios between the private and the public sector, a fiscal analysis is performed to evaluate the return of investment for the government as the funding agent. This is done under some assumptions:

- The tax incomes considered were:
  - Marginal increase of oil & gas royalties
  - Marginal increase of the income tax due to the decrease in the transportation cost
- Two parallel analyses are performed: one considering only the liquid cash flow of the government (taxes vs. investment)–this will be the view of the Secretary of Treasury–and a more comprehensive analysis studying the total benefits of the investment (including saving in externalities)–i.e. view of congressmen.

The results of both analyses look for the governmental incentives to invest in infrastructure because of the high potential savings in economic resources (i.e. road maintenance).

4.2.5. Decision scenarios

With all this information, some decision scenarios can be proposed in order to analyze the different paths that lead to the socially optimal solution.

As was introduced before, a variety of outcomes are possible, but the objective in any case will be to achieve the socially optimal solution through a process in which the private company incentives are in line with the common good. And this could be achieved only through a process of negotiation that, as was also mentioned before, needs useful information. The objective of SEFAM is the generation of this information, giving to the decision maker different choices to implement the optimal alternative. The differences between these choices are going to be mainly related to the institutional architecture needed for the implementation and the political support required. These are different paths to achieve the same final objective.

After presenting SEFAM, the following section will summarize the value added by this model with respect to current traditional analysis and Section 4.4 will apply it to the East-West VM supply corridor.

4.3. VALUE ADDED BY SEFAM

As was introduced in Section 4.1, the value added by SEFAM is related to the generation of new information through a simultaneous economic and financial analysis that together with a fiscal assessment will develop new possible alternatives and sub-alternatives that would not been generated if each actor performed a separate analysis (i.e. if the government developed an economic analysis and the private sector a financial evaluation, Figure 4-6). This new possibility of interaction in a defined framework allows the decision makers to increase the variety of possible solutions and creates better information for the prospective negotiation process. As will be seen in the next section, the analysis of the VM research case started with some basic alternatives that then were expanded with the implementation of SEFAM, generating of a new set of sub-alternatives (B2.1, B2.2 and B3.1@ different interest rates). At the end, these were different ways of implementing the socially optimal alternatives (in the VM case, the railroad), but were created due to the simultaneous analysis of SEFAM.

The existing literature is basically organized in two clusters: on one side, authors that analyzes the methods of Benefit-Cost Analysis and on the other those who study the Public Private Partnerships or others instruments of private sector participation in infrastructure investments. In the first group, authors like Kurowski et al. (2011) and Zeber (1994) analyze the BCA and tangentially discusses the “divergence of private and social cost” by making meticulous analysis of how to implement the BCA. In the second group, authors such as Delmon (2009), Merna et al. (2002) and Grigg (2010) focus on the potential benefits of involving the private sector in financing infrastructure and detailing the characteristics that a PPP, or similar structure, must have to be successful. Both groups include a very interesting analysis of each topic, but the author believes that SEFAM is in the middle between these two clusters, because it uses the cost evaluation of the BCA in a context of a simultaneous analysis with the financial evaluation of the private sector, and seek to provide information to understand a previous decision: how to align the private incentives to achieve the social optimal alternative. Then, it opens the debate on what should be the best instrument for its implementation, where Delmon (2009), Merna et al. (2002) and others author's analysis are certainly very useful.

Seeking to clarify the value added by this simultaneous analysis, Figure 4-6 shows how SEFAM includes into the same discussion the two visions, hoping to align the incentives of the private sector to implement the socially optimal alternatives.

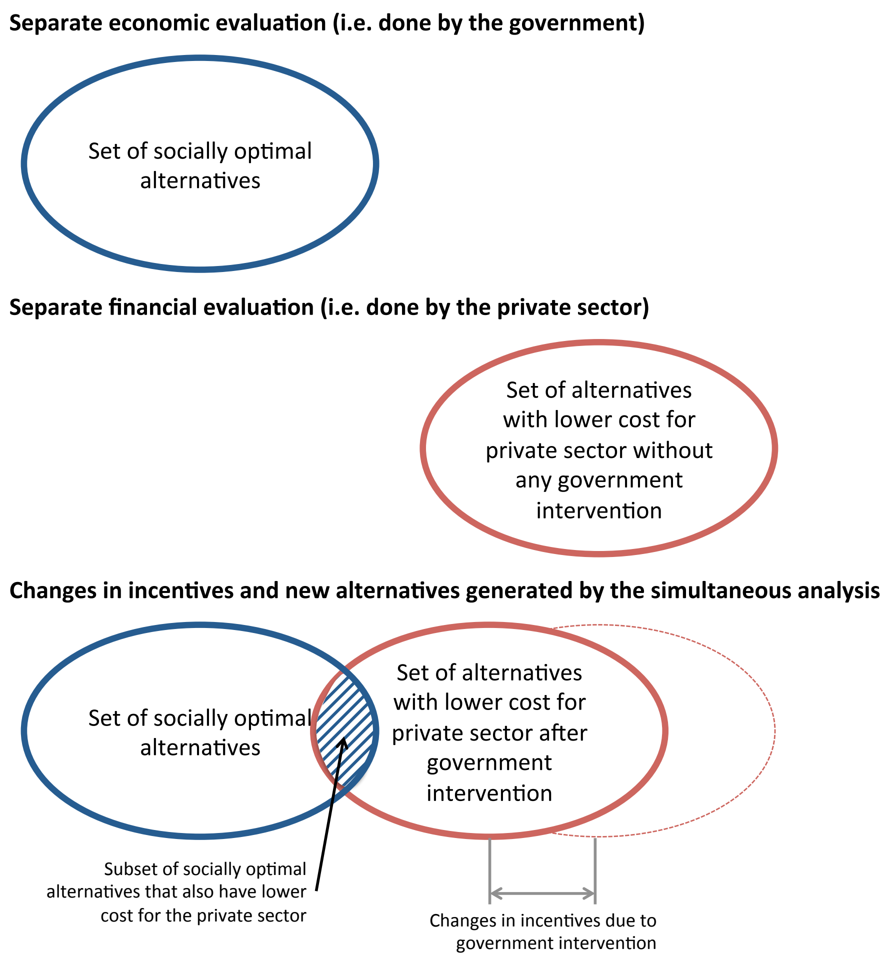


Figure 4-6 Interaction of the simultaneous economic and financial analysis (Author)

As will be seen in the next section, there are very different options of government intervention: for example subsidize the most efficient alternatives by directly investing in infrastructure (since there are social benefits that are not monetized, i.e. environment), to lender funds to finance large capital investments (sovereign funds have less financial cost) or even charging sub-optimal alternatives to favor the most efficient alternative by comparison (e.g. charging trucks for the pollution caused).

SEFAM ultimately allows not only to systematize the reasoning process in a model framework, but also to create new sub-alternatives, generated by this interaction and modification of incentives, that a priori would not be seen by separate analyzes. The next section provides the proof of concept of the application of SEFAM to a specific case.

4.4. IMPLEMENTATION OF SEFAM TO THE RESEARCH CASE OF VM

4.4.1. INTRODUCTION TO THE CORRIDOR

As was briefly mentioned in Section 1.3, the author selected the East-West VM supply corridor between Bahía Blanca and Neuquén as the research case for the scope of this thesis for the following reasons:

1. Because of the location of the origins of the inputs required by VM exploitation and the importance of the Buenos Aires and Bahía Blanca ports, this corridor is going to be essential for the development of VM. A significant portion of the cargo transported to VM will use this corridor.
2. This East-West corridor is crucial for the connectivity of the northern part of Patagonia and has had both highway and railroad infrastructure competing for more than a century.
3. Between Choele-Choel and Neuquén (Figure 4-7) in the valley of the Río Negro, the National Highway N 22 (RN22) is considered the backbone of the valley, serving all the communities and being the main infrastructure for the movements of persons and goods. This highway is the location of frequent accidents because it has an old design[24] and passes through the centers of many communities. It is also one of the busiest routes with one lane per direction in the country, making it difficult to think that it can withstand more traffic without complaints from neighbors and local and provincial authorities.
4. The Bahía Blanca-Neuquén branch of the Roca Railway (now under Ferrosur Roca concession) is in poor condition (Martínez 2014). Investments are required to achieve an efficient operation for the level of traffic that the full exploitation of VM requires, but faced with the latest announcements of March 2015, mentioned in Section 3.3, about changes in

[24] RN22 has one lane in each direction in most sections and a second lane is under construction between Cipoletti and Villa Regina.

national railway policy, it is unclear who should make these investments and how (the rail concessionaire, the operator, the national government, etc.).

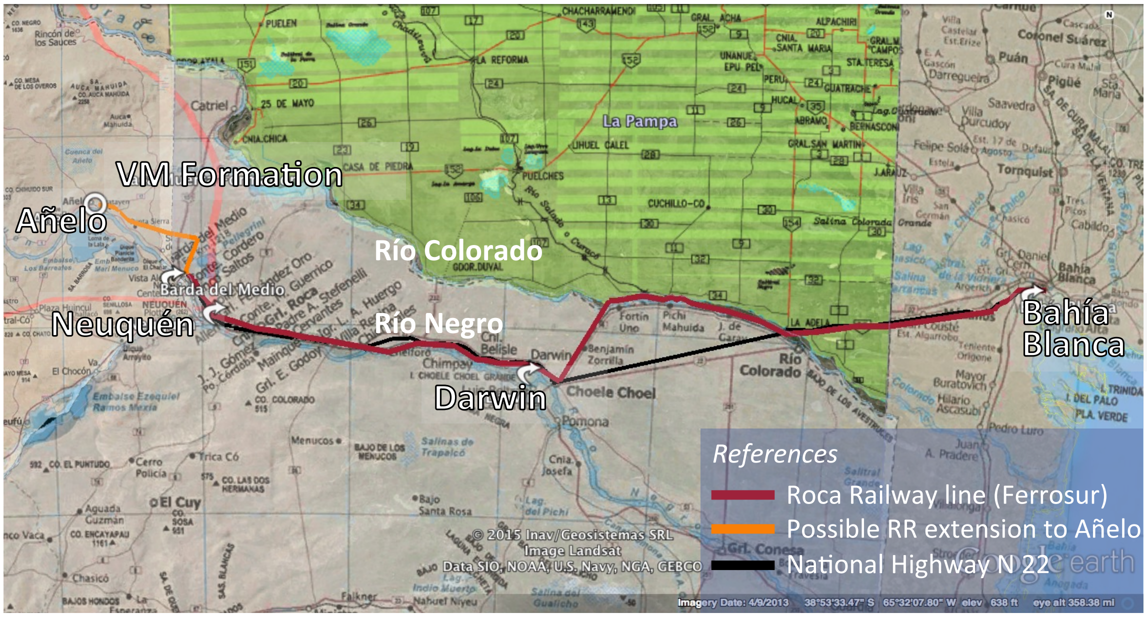


Figure 4-7 Detailed map (Author adapted from Google Earth and provincials official cartography)

The English company Buenos Aires Great Southern Railway (known in Argentina as Ferrocarril del Sud) between 1896 and 1901 constructed the railway line between Bahía Blanca and Neuquén with intermediate openings in: Río Colorado (1897), Choele Choel (1898) and Cipoletti (1899), as part of its network that covered the southern part of the Province of Buenos Aires[25]. This Neuquén line was promoted by the National Government, who was seeking to have a fast access to the border with Chile because of the threat of a potential war due to diplomatic tensions by the late nineteenth century. Paradoxically, this was a perfect example of effective synchronization between public and private sector, which managed to build in less than three years more than 500 kilometers of railways in very difficult conditions: the line crosses a desert that was the Argentine Far West and technology of 1890s. The following segment between Cipoletti and Barda del Medio was constructed in 1910 as a dedicated branch for the construction of the Ballester dam, and later was disabled. All these segments were then included in the Roca Railway line with Peron's railway nationalization of 1948 and since 1993 have been part of Ferrosur Roca private concession.

The Dirección Nacional de Vialidad (DNV) named the road between Bahía Blanca and the border with Chile (Paso Pino Hachado) National Highway 22 (RN22) in 1935 (CAC 2010). The original path was completely parallel to the Roca Railway line, but when the highway was paved in the 1960s it

[25] "Inauguración oficial de la Prolongación de Bahía Blanca al Neuquén", Ferrocarril del Sud, 1899. Retrieved from the website: http://www.archive.org/stream/ferrocarrildels00airegoog#page/n2/mode/2up on April 20, 2015.

was decided that a shortcut between Choele Choel and Río Colorado was a better solution, making it 25 km shorter[26].

As was shown in Section 3.4, the initial bundles of strategic alternatives identified for the VM case are the ones included in Figure 4-8.

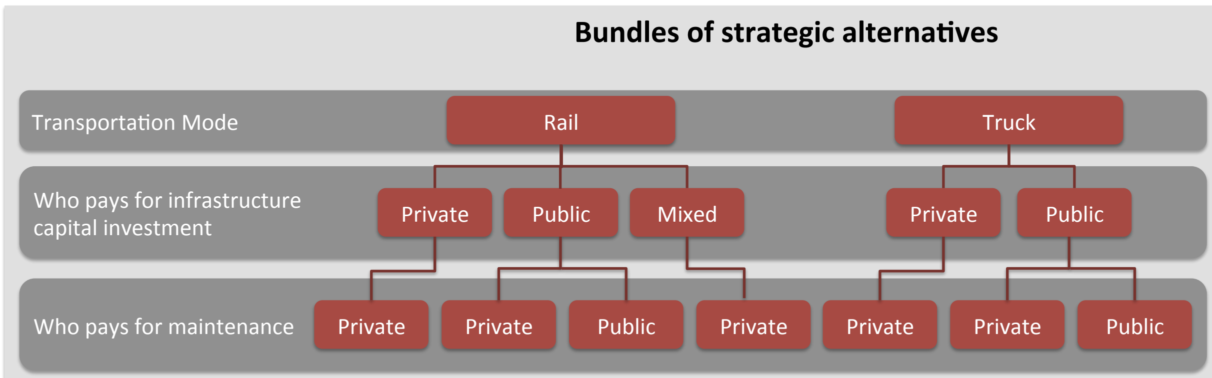


Figure 4-8 Bundles of strategic alternatives for developing logistics infrastructure in the East-West VM supply corridor —Research case—(Author)

In this research case, the rail alternatives will be based on the use of the railway infrastructure (existing and new) between Bahía Blanca and Añelo. The trucking alternatives will include the use of RN22 (Bahía Blanca-Neuquén) and the Provincial Road N 7 (RP7 Neuquén-Añelo).

4.4.2. Implementation of Global Economic Assessment for VM

For this first phase, since it is a global analysis from the perspective of the whole society, it is irrelevant which actor pays for the capital investment or the maintenance. Hence, two alternatives will be analyzed: rail and truck (the first level in the bundle of strategic alternatives).

For the scope of this thesis, and since this research case is constructed in order to provide an example of the application of SEFAM, it will consider Bahía Blanca as the origin of loads (step 1) and the total quantity of input to be transported as 1 million tonne per year (step 2). Regarding the alternatives to be considered (step 3), there are going to be two:

- Alternative A: trucks using RN 22 and RP 7.
- Alternative B: railroad using Bahía Blanca-Neuquén-Añelo infrastructure.

[26] According to the website of the Cámara de Diputados of Buenos Aires Province: http://www.hcdiputados-ba.gov.ar/proyectos/10-11d20420.doc

Table 4-2 Details of alternatives A and B (Author)

Alternative A

Highway number	Section	Km
RN 22	Bahía Blanca - Neuquén	535.0
RP 7	Neuquén - Añelo	99.8
		634.8

Alternative B

	Section	Length (km)	Status
1	General Cerri (km 654.0) - Cipoletti (km 1188.2)	534.2	In service @20 ton/axle
2	Cipoletti (km 1188.2) - Contralmirante Cordero (km 1218.6)	30.4	Disabled. Require complete renovation.
3	Contralmirante Cordero (km 1218.6) - Añelo	90	Completely new
		654.6	

Since both alternatives will use existing modes of transportation, they are considered technically feasible (step 4).

For the estimation of traffic, we will make the following considerations:

Table 4-3 Transportation capacity by unit (Author)

Truck

Gross vehicle weight	45[27]	tonne/unit
Tractor tare	5,5	tonne/tractor
Trailer tare	8,4	tonne/trailer
Unit tare	13,9	tonne/unit
Payload	31,1	tonne/unit

Double trailer units

Gross vehicle weight	75[28]	tonne/unit
Tractor tare	6,5	tonne/tractor
Trailers tare	16,8	tonne/trailers
Unit tare	23,3	tonne/unit
Payload	51,7	tonne/unit

Railroad

Gross car weight	80[29]	tonne/railcar
Railcar tare	22	tonne/railcar
Payload	58	tonne/railcar

[27] Maximum weight according to the Ley de Nacional Tránsito (Law 24.449-Decret 779/95-Decret 79/98-RES. S.T. 497/94).
[28] According to Decret 574/2014 of April 22, 2014.
[29] Considering a 20 tonne per axle infrastructure and 4-axles railcars.

Even if double trailer units had an initial approval (2014) to circulate on national highways[30], its regulation has not yet been completed, so the service is not yet commercially offered. The author considers it useful to include them in Table 4-3, since if are implemented in the coming years, it could represent efficient alternatives to road transport.

With this information and considering 320 days per year of operation, it is possible to compute the total number of trips generated on each alternative (step 5), shown in Table 4-4.

Table 4-4 Number of trips per alternative (Author)

			Alternative A: Truck	Alternative B: Rail
Truck	Gross Vehicle Weight	tonne/unit	45	
	Tractor tare	tonne/tractor	5.5	
	Trailer tare	tonne/trailer	8.4	
	Unit tare	tonne/unit	13.9	
	Payload	tonne/unit	31.1	
	Trucks trips generated	trips/day	101	
	Length of the trip	Km	635	
	Average speed	Km/hr	50	
	Cycle time	days (incl. 12 hr rest by each 12 working hr)	2.12	
	Fleet	units	214	
Rail	Maximum weight per axle	tonne/axle		20
	Railcar tare	tonne		22
	Railcar payload	tonne		58
	Railcar per train (4 axles per car)	railcars/train		75
	Payload per train	tonnes/train		4350
	Total train weight (excl. locomotives)	tonnes		6000
	Number of axles	axles (max: 300)		300
	Trains per day	trains/days		0.7
	Trains every:	days		1.4
	Length of the trip	Km		654.6
	Average speed	Km/hr		30
	Cycle time	days (2 hr stopped every 12 hr of operation for driver change)		2.12
	Fleet	unit trains		1.52

In both cases (alternatives A and B), all the traffic generated will use the previously detailed infrastructure, because only one origin and one destination of loads are considered.

[30] Decret 574/2014 of April 22, 2014.

The evaluation of capacity impact on existing infrastructure (step 6) is divided into two categories: structural and traffic.

The structural analysis is done for the highway alternative (alternative A) and in particular in the RN 22 segment that is the most important part and for which there is public traffic data (AADT[31]) available. In the case of the railroad, the condition of the existing infrastructure is poor and requires investment in any scenario (Martínez 2014).

As we discussed in the previous section, since there is no information about the current status of the pavements, the author proposes to use a marginal analysis to evaluate the economic cost of the infrastructure consumed due to traffic generated by VM. To start this analysis, the traffic information on the RN 22 is included in Figure 4-9, indicating the main urban centers crossed.

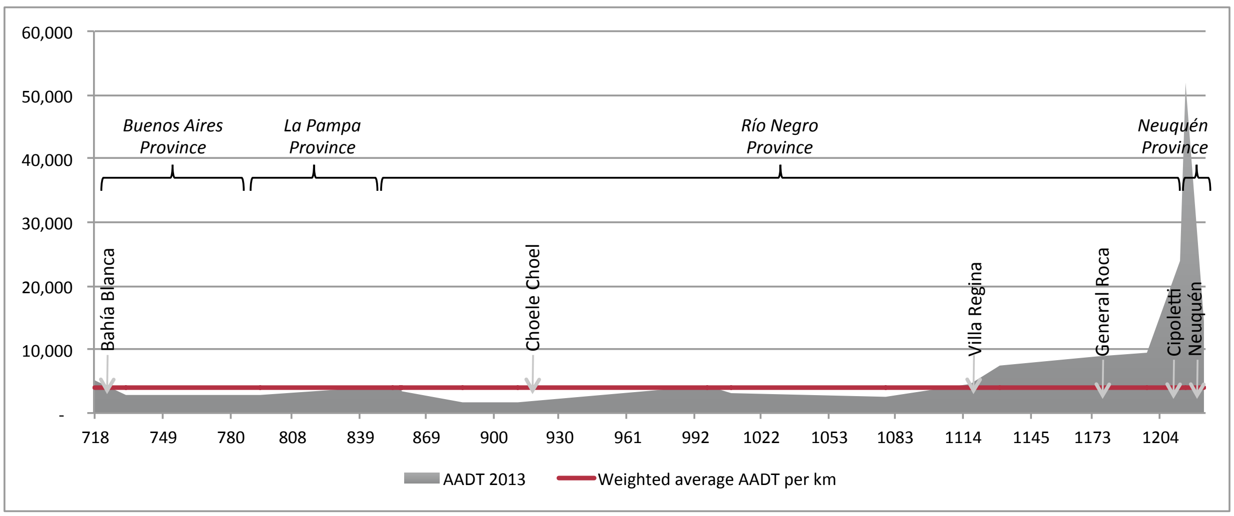


Figure 4-9 Traffic (2013) profile on RN 22 on each km, identifying the cities and provinces it crosses (Author with data from DNV)

Using the methodology described in AASHTO "Guide for Design of Pavement Structures" (4th edition Appendix D) 1993 it is possible to calculate the ESAL (Equivalent Single Axle Load) produced by VM operation and to compare with the "normal" deterioration of the road under current conditions. The conclusions are shown in Table Table 4-5: the number of ESALs produced by VM will be equivalent to 16% of the ESAL produced by normal traffic on the RN 22

Table 4-5 Impact of VM on RN22 road deterioration (Author)

				Alternative A		
Highways	Weighted AADT	% of Trucks	ESALS estimate in 15 years (W18)	Loaded truck trips	Unloaded truck trips	ESAL added in 15 years
RN 22	3893	43.5	1.75E+07	101	101	2.82E+06

[31] Annual Average Daily Traffic

Regarding the impact on the traffic congestion (step 7) on RN 22, the first thing to notice is that the percentage of trucks will increase from 43.5% (2013) to 46.3% creating a direct impact on the local traffic and the communities along the road. At the same time, by using the methodology described in Chapter 20 of the Highway Capacity Manual (HCM 2000) it is possible to compute the Percent Time Spent Following (PTSF), that is a direct measure of the inefficiencies produced by congestion. The implementation of the HCM methodology is included in the Appendix and the conclusions are shown in Table 4-6: the traffic generated by VM will produce more than 135,000 hours of delay to the current users.

Table 4-6 Impact on congestion by traffic generated by VM (Author)

				Alternative A				
Highway	Weighted AADT	% of Trucks	Length	Additional trucks	New AADT	New % of trucks	Percent Time Spent Following (PTSF)	Number of additional hours in traffic due to congestion produced by VM traffic
RN 22	3893	43.5%	635	202	4095	46.3%	66%	**135,065**

By implementing the Dell'Acqua (2010) model, mentioned in Section 4.2.1, we are able to estimate the number of additional accidents produced by traffic generated by VM: 3.3% additional accidents on the RN22 (Table 4-7).

Table 4-7 Impact on the number of road accidents by traffic generated by VM (Author)

					Alternative A				
Highway	Weighted AADT	% of Trucks	Length	Accidents/year	Additional trucks	New AADT	New % of trucks	Accidents with VM	% increase in accidents
RN 22	3893	43.5	635	386.7	202	4095	46.3	399	3.3%

For the current implementation, the accidents of Table 4-7 are the ones that involve fatalities. To compute the number of serious injuries comparing to the number of fatalities, a factor of 10 was used according to McMahon et al. (2008).

Then, by computing the amount of fuel burned by each alternative and using the coefficient of generation of CO_2 published by the Argentine Secretary of Energy, it is possible to determine the level of impact on the environment due to CO_2 emissions. As was expected, the trucking alternatives generate almost 10 times more emissions than rail alternatives and the overall results are shown in Table 4-8.

Table 4-8 Fuel burned and CO_2 generated by alternative (Author)

		Alternative A	Alternative B
Mode		Truck	FFCC
Truck/day or trains/day		101	0.72
Payload per trip	ton	31.1	4350
Length of the trip	km/trip	634.8	654.6
truck-km/year or locomotive-km/year	millions	**41.03**	**0.30**
truck-km/year or locomotive-km/year loaded	millions	*20.51*	*0.15*
truck-km/year or locomotive-km/year unloaded	millions	*20.51*	*0.15*
Fuel consumed/year	**millions liters/year**	**15.14**	**1.66**
Fuel consumed/year loaded	*millions liters/year*	*8.41*	*0.98*
Fuel consumed/year unloaded	*millions liters/year*	*6.72*	*0.68*
CO_2 generation (tonne/year)	**tonne/year**	***40,987***	***4,501***

After computing the externalities, it is necessary to determine the capital expenditures required for each alternative.

In the case of railroad, the specification of the required construction works and its costs are included in Table 4-9.

Table 4-9 Railroad construction works (Author)

N	Section	Length (km)	% respect to new infrastructure
1	General Cerri (km 654.0) - Cipoletti (km 1188.2)	534.2	50%
2	Cipoletti (km 1188.2) - Contralmirante Cordero (km 1218.6)	30.4	90%
3	Contralmirante Cordero (km 1218.6) - Añelo	90	100%

The railroad investments for a new track per km considered for the evaluation was $ 1.3 million per km, according to the national government construction procurements of 2012 and 2013 for the Ferrocarril General Belgrano.

For the road infrastructure, the analysis is again marginal: for the economic assessment the required construction works are the compensation for the number of ESAL (Equivalent Single Axle Load) consumed and the value of each ESAL is computed dividing the total cost of road reconstruction ($ 1.2 million) over the expected number of ESAL added by this investment ($4.2*10^6$). The same procedure was done for the road maintenance cost, considering a cost of $12,500 per km-year.

Regarding the operational cost, using the statistics of the Federal National Highway Administration, it is possible to compute the overall cost per tonne (Table 4-10) for the trucking alternatives.

Table 4-10 Economic operating cost (Author)

		Alternative A
Mode		Truck
Truck/day or trains/day		101
Payload per trip	tonne	31.1
Length of the trip	km/trip	634.8
Truck-km/year or locomotive-km/year		**41,033,472**
Truck-km/year or locomotive-km/year loaded		*20,516,736*
Truck-km/year or locomotive-km/year unloaded		*20,516,736*
Speed distribution per trip		
% of trip at 80 Km/h		*10%*
% of trip at 60 Km/h		*20%*
% of trip at 45 Km/h		*25%*
% of trip at 30 Km/h		*25%*
% of trip at 20 Km/h		*20%*
Unit weighted operative cost	**AR$ Sept12/km**	**21.24**
Operating cost	**$/year**	**137,461,007**
Cost per tonne	*$/tonne*	*137.5*

For the rail alternatives, an international standard of $0.04 per tonne-km was adopted that included the variable cost of operation without the infrastructure and rolling stock amortization. For the maintenance cost, $0.006 per gross tonne-km was adopted.

With all this information it is then possible to compute the present value of the total economic cost over the 15-year period with a discount rate of 12%, in order to compare different types of alternatives. This discount rate is the one established in the Resolution SPE 0110/1996 of the Argentine Secretary of Economic Programming[32] and is also the value utilized by the multilateral credit agencies to evaluate infrastructure projects (e.g. World Bank or InterAmerican Development Bank). The complete economic analysis is included in the Appendix of this thesis and the main results are presented in Table 4-11.

[32] This resolution was formally repealed in 2001 (SPE 0013/2001), but the widespread use of a discount rate of 12% is maintained.

Table 4-11 Results Global Economic Assessment (Author)

	Alternative A	Alternative B
Total volume transported in 15 years	15,000,000	15,000,000
truck-km	615,502,080	
ESAL produced	2,822,764	
railcar-km		338,586,207
tonne-km		19,638,000,000
Gross Ton Km		27,086,896,552
Road Infrastructure investment	USD 338,922,237	
Railroad Infrastructure investment		USD 443,308,707
Road Infrastructure Maintenance cost	USD 36,322,388	
Rail Infrastructure Maintenance cost		USD 63,083,972
Rolling Stock Investment		USD 20,767,857
Road operational cost	USD 1,323,438,274	
Rail operational cost		USD 611,751,349
Congestion cost	USD 11,147,738	USD 1,461,391
Accidents cost	USD 315,555,725	USD 62,003,557
Greenhouse emissions cost	USD 1,758,716	USD 398,379
NPV total cost in 15 years	**USD 2,027,145,077**	**USD 1,202,775,212**
$ current/tonne	**USD 135.1**	**USD 80.19**
Operational	USD 88.2	USD 40.8
Externalities	USD 21.9	USD 4.3
Infrastructure investments (capital+maintenance)	USD 25.0	USD 35.1

4.4.3. FINANCIAL EVALUATION OF ALTERNATIVES FROM A PRIVATE COMPANY PERSPECTIVE FOR VM

For the financial evaluation, the specific sub–alternatives names are included in Figure 4-10.

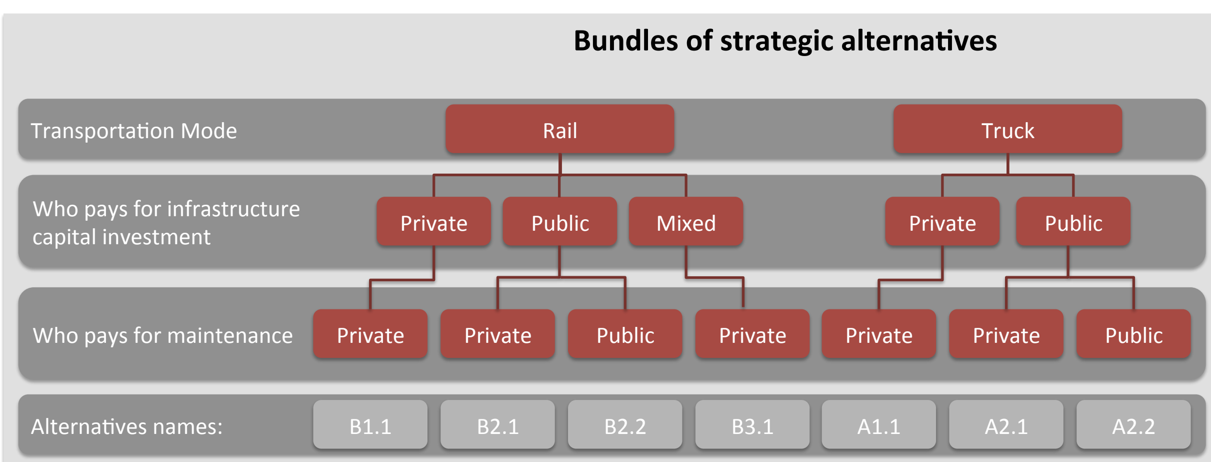


Figure 4-10 Alternatives for the Financial Analysis in the bottom row (Author)

The first 5 steps are the same as the ones in the Global Economic Assessments by group of alternatives (A or B).

For the road operational cash flow cost, the DNV statistics are also used. In the case of railroad, the cash flow operational cost is computed as the economic cost plus taxes.

Then, all the information is again compiled in a 15–year cash flow with a discount rate of 15% that represents the value of the money for a private company. The results are shown in Table 4-12:

Table 4-12 Results of financial evaluation of alternatives (Author)

	Alternative A1.1	Alternative A2.1	Alternative A2.2	Alternative B1.1	Alternative B2.1	Alternative B2.2
Gvt Interest rate (Alt B3.1)						
Road capital investment cost	USD 411,379,646	USD -	USD -			
Road maintenance cost	USD 42,072,154	USD 42,072,154	USD -			
Road operational cost	USD 1,291,578,396	USD 1,291,578,396	USD 1,291,578,396			
Rail infrastructure investment				USD 593,952,847	USD -	USD -
Rail infrastructure Maintenance Cost				USD 71,588,523	USD 71,588,523	USD -
Rolling Stock Investment				USD 27,288,136	USD 27,288,136	USD 27,288,136
Rail operational cost				USD 497,340,689	USD 497,340,689	USD 497,340,689
Road operational cost (1st year)				USD 192,071,244	USD 192,071,244	USD 192,071,244
NPV	**USD 1,745,030,196**	**USD 1,333,650,550**	**USD 1,291,578,396**	**USD 1,382,241,439**	**USD 788,288,592**	**USD 716,700,069**
Total volume transported in 15 years	15,000,000	15,000,000	15,000,000	15,000,000	15,000,000	15,000,000
$ current/tonne	**USD 116.3**	**USD 88.9**	**USD 86.1**	**USD 92.1**	**USD 52.6**	**USD 47.8**

	Alternative B3.1@15%	Alternative B3.1@10%	Alternative B3.1@8.75%	Alternative B3.1@5%	Alternative B3.1@0%
Gvt Interest rate (Alt B3.1)	*15.0%*	*10.0%*	*8.75%*	*5.0%*	*0.0%*
Road capital investment cost					
Road maintenance cost					
Road operational cost					
Rail infrastructure investment	USD 593,952,847	USD 459,612,644	USD 425,968,017	USD 325,822,821	USD 196,550,115
Rail infrastructure Maintenance Cost	USD 71,588,523	USD 71,588,523	USD 71,588,523	USD 71,588,523	USD 71,588,523
Rolling Stock Investment	USD 27,288,136	USD 27,288,136	USD 27,288,136	USD 27,288,136	USD 27,288,136
Rail operational cost	USD 497,340,689	USD 497,340,689	USD 497,340,689	USD 497,340,689	USD 497,340,689
Road operational cost (1st year)	USD 192,071,244	USD 192,071,244	USD 192,071,244	USD 192,071,244	USD 192,071,244
NPV	**USD 1,382,241,439**	**USD 1,247,901,236**	**USD 1,214,256,609**	**USD 1,114,111,413**	**USD 984,838,707**
Total volume transported in 15 years	15,000,000	15,000,000	15,000,000	15,000,000	15,000,000
$ current/tonne	**USD 92.1**	**USD 83.2**	**USD 81.0**	**USD 74.3**	**USD 65.7**

For Alternative B3.1, it was considered that the government acts as a lender and as a compensation requires a specific interest rate. In order to evaluate the sensitivity to this interest rate, five different values were used: 15%, 10%, 8.75%, 5% and 0%. It is noted that the result of the 15% interest rate case is equal to the Alternative B1.1 result, since the interest rate of the lender (the government in this case) is equal to the discount rate of the private company. Then, this is the upper bound since it would be the rate of indifference: the government does not contribute.

Following the ideas presented in Zerbe et al. (1994), the coupon rate of government bonds or its yield could be used as a way to measure the financing cost for the government. Along these lines, an alternative using 8.75% as government interest rate was included, equal to the value of the coupon of the BONAR 2024 bond, re-issued by the Argentine government in April 2015.[33] The detailed results of this financial evaluation are included in the Appendix.

4.4.4. *Simultaneous Economic-Financial comparison of alternatives for VM*

For the case of the East-West VM supply corridor, in economic terms the comparison shows a clear advantage of using rail alternatives over trucking. Roughly the economic savings for society of using rail are about 40% of the cost (Figure 4-11), driven mainly by the savings in externalities (cost of accidents, congestion and greenhouse emissions) and operational efficiencies (basically less fuel consumed by tonne-km together with lower labor per tonne-km). Finally, the cost of infrastructure is higher in the rail alternatives, but is modest in comparison with the savings in the other categories.

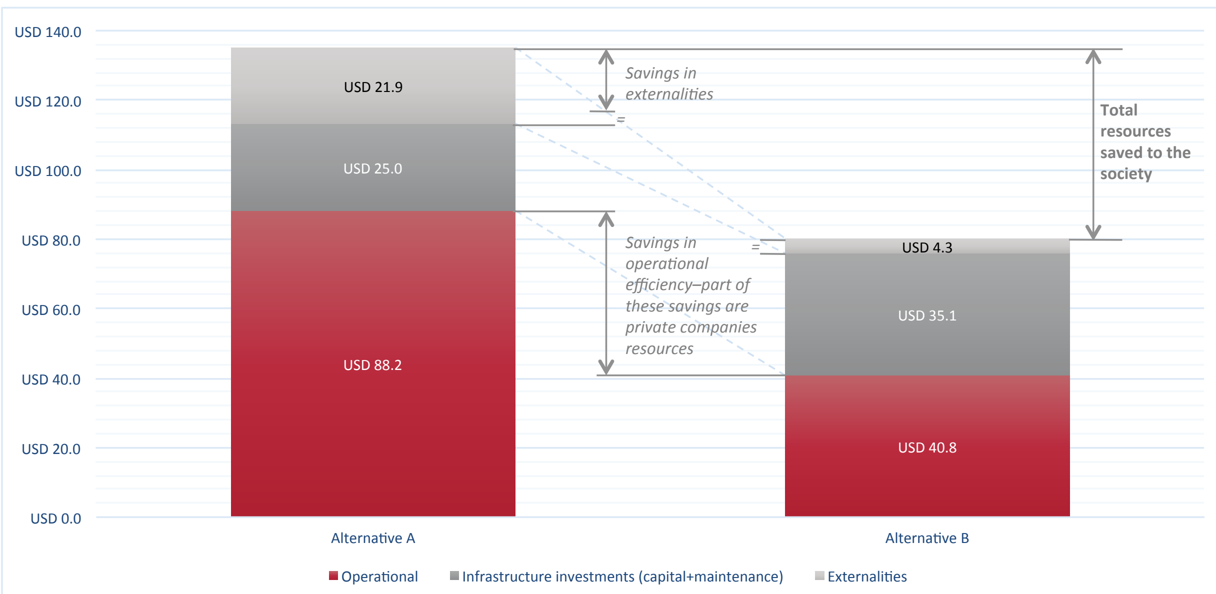


Figure 4-11 Results Global Economic Assessment (Author)

One might think that this result was a-priori expected, since both the distance and the volume are high and seam to be appropriate for the use of railway technology; this was verified with the results obtained.

Therefore the first conclusion of this research case is that the rail alternative is the most efficient for the society and therefore the government, as guardian of the common good, should ensure that it is the mode selected, verifying and acting if the incentives of private companies are not aligned with this overall objective.

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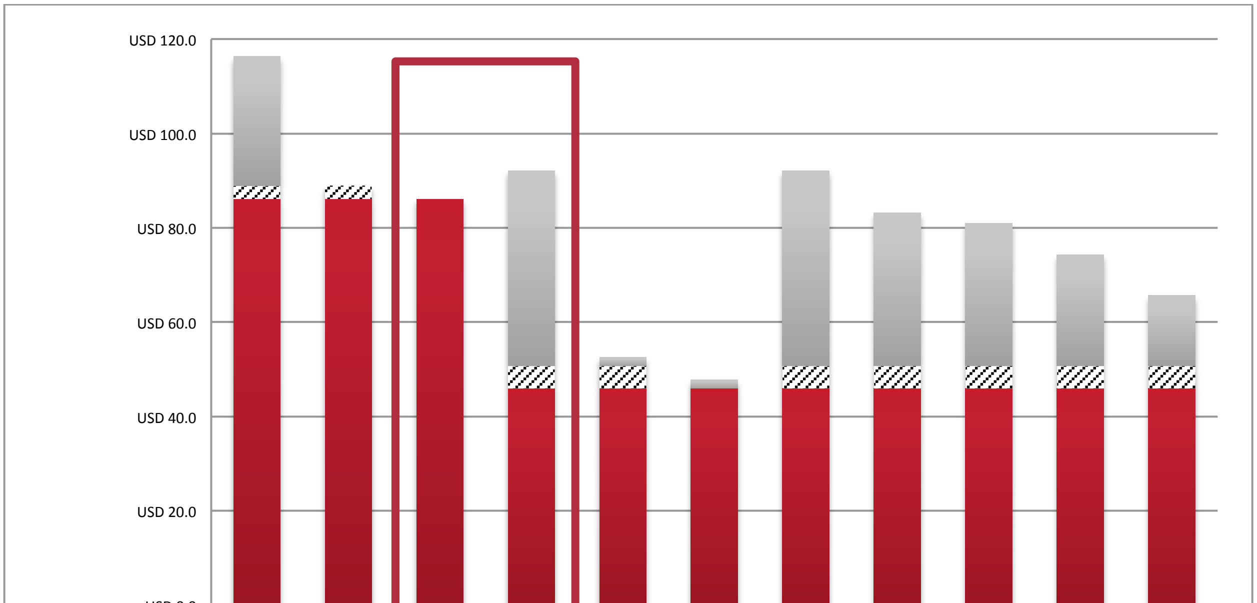
[33] According to Banco Comafi Research Department "Fixed Income Report", February 13, 2015: http://www.comafi.com.ar/multimedios/pdfs/inversiones/actualidad/AY24.pdf

The best way to verify the incentives is to check the prices that companies will pay for the different services; this reflects their willingness to pay and at the end will be the driver for making decisions. The alternatives analyzed included 3 trucking alternatives and 4 main rail alternatives of which the last one has 5 sub–alternatives (Figure 4-12).



	Alternative A1.1	Alternative A2.1	Alternative A2.2	Alternative B1.1	Alternative B2.1	Alternative B2.2	Alternative B3.1@15%	Alternative B3.1@10%	Alternative B3.1@8.75%	Alternative B3.1@5%	Alternative B3.1@0%
Capital Investment	USD 27.4	USD 0.0	USD 0.0	USD 41.4	USD 1.8	USD 1.8	USD 41.4	USD 32.5	USD 30.2	USD 23.5	USD 14.9
Maintenance	USD 2.8	USD 2.8	USD 0.0	USD 4.8	USD 4.8	USD 0.0	USD 4.8	USD 4.8	USD 4.8	USD 4.8	USD 4.8
Operational cost	USD 86.1	USD 86	USD 86	USD 46	USD 46	USD 46	USD 46	USD 46	USD 46	USD 46	USD 46

Figure 4-12 Results financial evaluation of alternatives for a private company in current $/tonne by type of cost (Author)

The alternatives available for the private companies in a status-quo situation, meaning what is available today under current conditions and without any intervention or regulation of the government, are the one included in the red rectangle in Figure 4-12:

- **Alternative A2.2:** is the use of trucks in public infrastructure where private companies do not pay directly for the maintenance or replacement of the road structural capacity consumed, or for externalities produced.
- **Alternative B1.1:** is the totally private rail alternative, where the private sector makes the whole investment required, including capital works and purchasing of rolling stock, without any governmental assistance.

As could be seen in Figure 4-12, the incentives (shown by the price) for a private company in a status-quo situation will tend to the selection of the Alternative A2.2 (comparison under the red rectangle of Figure 4-12) that is not the optimal solution for the society as a whole. Up to this point, we have several possible alternatives to try to align the incentives. As was discussed in the first part of this chapter with the theoretical presentation of SEFAM, the problem here is that the decision maker in the real economy does not perceive from the market all the real costs generated, encouraging him or her to make sub–optimal decisions; this problem is typical in transport economics.

Against this, the government has different tools to correct the distortion. On one side it could charge the trucks the actual costs produced with some form of taxes or fee. Another possibility, since this is a marginal decision problem between alternatives, is to subsidize in some way the most socially efficient alternative. In the Argentine context, the author believes that this would be the only viable option, given the strong influence of the labor union of truck drivers and the potential effect of the lobby of trucking companies.

The ways to materialize this subsidy or incentive are also varied. This analysis computes three ways:

- Subsidize 100% of the railroad construction costs (Alternative B2.1)
- Subsidize 100% of the railroad construction costs, together with the maintenance (Alternative B2.2)
- Finance the capital infrastructure (Alternatives B3.1). Under this scenario, the subsidy is over the spread between the financing costs for the private sector vs. the government.

Obviously from the private perspectives, the alternatives B2.1 and B2.2 are the most attractive, since the sector is receiving a direct and very significant subsidy.

The question is: why is help with financing effective and appropriate? Basically as mentioned in Section 1.1, since the rail alternatives are very capital–intense, differences in the financing cost can change the parameters of the decision, and with this correct the incentive for the private sector. This is an intermediate alternative because at the end, the private sector ends up paying for the entire infrastructure, including the cost of financing, but the government supports by reducing this cost assuming part of the risk.

This idea that financing with sovereign funds has lower costs is specifically true in the developing world, where private financing mechanisms or project financing are far less developed than in the US or UK. Merna et al. (2002) states: “in the case of most developing countries the government is the most creditworthy entity and is able to borrow at the lowest rates, making possible infrastructure projects that might not otherwise be financially viable.” In this sense, the analysis made by Delmon (2009) in which discusses ways of financing infrastructure between public and private sectors, distinguishing the main characteristics of each, is particularly interesting.

It is interesting that the latest series of sub–alternatives inside B3.1 could also be thought of as Open Access situations in which the government makes the investment and charges the private operators a toll, equivalent to the cost of infrastructure plus an interest to compensate for the financing cost. This framework could ensure fair competition for the use of the infrastructure to guarantee the pursuit of efficiency for all current or future operators.

4.4.5. FISCAL ANALYSIS AND RETURN ON INVESTMENT FOR THE PUBLIC SECTOR FOR VM

To determine if this could be a good investment for the Argentine government, a fiscal analysis is done, including an evaluation of the return on investment for the public sector. This analysis is made in the worst-case position from the government’s perspective: Alternative B2.2 in which it pays for the capital infrastructure and the maintenance.

Table 4-13 Analysis of additional income for the government due to VM (Author)

	Alternative B2.2
Total rail infrastructure investment in Alternative B2.2 (discounted million $)	506.4 M USD
INCREASE IN TAXES DUE TO VM	
Oil royalties	
Neuquén Basin	
Royalties per m^3 of oil (average period 2013-14)	USD 57.15
Royalties per barrel of oil (average period 2013-14)	USD 9.09
VM average production estimated (barrels/day)	50,000
VM average production estimated (barrels/year)	18,250,000
Additional royalties generated by VM's oil (million $)	165.8 M USD
Gas royalties	
Neuquén Basin	
Royalties per m^3 of gas (average period 2013)	USD 53.33
VM average production estimated (m^3/day)	3,000,000
VM average production estimated (m^3/year)	1,095,000
Additional royalties generated by VM's gas (million $)	58.4 M USD
Increase in Income Tax due to lower transportation cost	
Hypothesis: all the decrease in transportation cost is translated into additional income for the private company	
Annual operating savings for the private company (million $)	55.0 M USD
Increase in Income Tax paid @35% (million $)	19.2 M USD
Additional fiscal income per year (million $)	243.4 M USD

Table 4-13 shows the order of magnitude of the additional income for the government due to additional taxes collected due to VM operation versus the rail infrastructure cost.

Obviously the form of allocation of public resources is a very broad discussion, but this analysis simply tries to show that even if required rail investment are high, revenues from royalties are in the same order of magnitude (in this case, a factor of 2).

The cash flow for the government considering the additional income produced by VM is included in the Appendix of this thesis. The overall results (Table 4-14) show that from the government's perspective the investment in railroad infrastructure is a good decision from the perspective of the overall society and even from the perspective of the Secretary of Treasury, because the additional income in taxes and royalties will be significant.

Table 4-14 Return of investment analysis for the public sector (Author)

	Alternative B2.2
IRR considering additional income and savings in externalities	47%
IRR considering additional income only	44%

The point that should be mentioned is that when we speak of the public sector we are considering together the national and provincial government, since the first collects the income tax and the second oil and gas royalties. Therefore there must be coordination for the investment decisions that will definitely require consensus.

4.4.6. DECISION SCENARIOS FOR VM

This research case brought the discussion about social efficiency, private incentives and finally the role of the government in promoting the use of efficient transportation alternatives. The implementation of SEFAM in this particular supply corridor for VM showed that rail alternatives are significantly socially efficient but that would require public sector assistance for its implementation. In this regard, the author believes that the possible decision scenarios should be based on the series of sub–alternatives B3.1 analyzed, since these solve the problem of incentives for the private sector without having to commit large public resources in heavy subsidies to a sector that has considerable levels of private profits.

As was introduced in Section 4.3, the generation and evaluation of the series of sub-alternatives (B2.1, B2.2 and B3.1@ different government interest rates) that included government intervention to achieve the socially optimal solution was possible due to the simultaneous analysis presented by SEFAM. This increases the variety of possible solutions for the decision makers and creates better information for the prospective negotiation process, like in this case.

4.5. FINDINGS AND INITIAL CONCLUSIONS OF THE IMPLEMENTATION OF SEFAM TO THE VM RESEARCH CASE

The next chapter will address the final conclusions and recommendations of this thesis, but regarding specifically the implementation of SEFAM to the VM research case, these are the main considerations and findings:

- By analyzing the existing literature we found that we can organize it in basically two clusters: on one side, authors who analyzes the methods of Benefit-Cost Analysis (BCA) and on the other those who study the Public Private Partnerships (PPP) or other instruments of private sector participation in infrastructure investments. In the first group, authors like Kurowski et al. (2011) and Zerbe (1994) analyze the BCA and tangentially discuss the "divergence of private and social cost" by making meticulous analysis of how to implement the BCA. In the second group, authors such as Delmon (2009), Merna et al. (2002) and Grigg (2010) focus on the potential benefits of involving the private sector in financing infrastructure and detailing the characteristics that a PPP, or a similar structure, must have to be successful. Both groups include a very interesting analysis of each topic, but the author believes that SEFAM is in the middle between these two clusters, because it uses the cost evaluation of the BCA in a context of a simultaneous analysis with the financial evaluation of the private sector, and seeks to provide information to understand a previous decision: how to align the private incentives to achieve the socially optimal alternative. Then, it opens the debate on what should be the best instrument for its implementation, where Delmon (2009), Merna et al. (2002) and other author's analyses are certainly very useful.
- The application of SEFAM to the VM Research Case showed the application of the model in a specific case of analysis for the development of shale resources in Argentina. Within the scope of this academic thesis, we used available public information from indirect sources, using same global models and assumptions. The author suggests that to move towards a more accurate decision making process, information from primary sources would be essential. In particular the need to develop an analytical model of prediction of road accidents calibrated to the Argentine context is crucial. It would be also important to have detailed information of the current state of the available infrastructure though field works,

surveys and onsite engineering testing. This information could lead then to a more precise quantification of the works required for different operation level targets. The marginal analysis presented in this work is intended to be an initial approach.

- We believe that one of the main points of SEFAM is to highlight the need of a joint planning effort between the public and private sector, that is not restricted to the completion of a specific contract (like for example in the case of a PPP). This joint effort requires understanding the incentives of the actors and simultaneously identifying the conditions under which government intervention can be effective. Along these lines, SEFAM is a methodology for understanding this approach and encouraging this joint planning effort.
- In concrete terms for VM, the main results highlight the importance of the railroad to achieve the sustainable exploitation of shale resources. Its lower social impacts and the operational efficiency due to the high volumes of loads over long distances make this technology very competitive in the current scenario. Beyond this, the high infrastructure investment required turns the government into an essential actor for the implementation. For the research case, the application of SEFAM showed that just providing support as lender with lower interest rate to fund the construction, could be enough to transform the railway alternative into the cheapest for the private sector, without requiring to commit large public funds that could be used for other critical sectors (e.g. education of health). As was mentioned in Section 4.4.4, even within the B3.1 sub–alternatives many possible implementation options exist. Some of them are listed here:
    - The government acting only as a lender, recovering its investment during the course of the project
    - The government assuming the role of Infrastructure Manager acting in an Open Access context, deciding then the value of the toll for the private operations (that eventually could be zero)
    - The government acting as a complete supplier of rail transportation services, including train operations.
- It is interesting to mention, as a success story, the current management structure of the pipeline's operation in Argentina. As was detailed in Section 2.1.3.4, a consortium of oil and gas producers controls the operating company, by owning shares. This operational model in which the final stakeholder is also part of the operating company in solidarity can be an interesting strategy to achieve good operational efficiency and very market oriented behavior of the transportation company. At the same time, the oil and gas producers are

interested in having decision power over the transportation company to avoid monopolistic behavior and control its costs. Along these lines, it is important to establish clear rules of fair competition for eventual access to rail infrastructure to avoid discouraging the participation of new VM producers not included in the railway operator consortium. In this sense, Delmon (2009) states for the O&G industry: "Pipeline, gasification and regasification, and other treatment and/or transportation projects are normally sponsored by the company that plans to use its services. Where several companies intend to use the facility, they may club together to share capacity. Such projects are not usually undertaken for speculative purposes."

- With regard to the financing instruments, Merna et al. (2002) detailed the possible financing instruments available to developing countries such as Argentina. In particular they highlight the idea that the private sector is the largest global source of investment capital. In fact, in developing countries Foreign Direct Investment (FDI) is more important than official development assistance or foreign aid. At the same time, we highlight the importance of the Multilateral Credit Agencies in financing infrastructure projects over the last years in Argentina. Therefore, there are different ways of implementing both the public and private financing, which should be analyzed at the time of implementation.

The implementation of SEFAM in the East-West VM supply corridor has been successful in the sense that it drew some preliminary general conclusions that can guide the initial discussion. Of course this debate is open and will require much concerted effort to achieve sustainable operation to supply VM, but the cornerstone is to have joint planning as a key tool.

In the next chapter, Chapter 5, the conclusions of this thesis are presented together with the description of potential areas of future research.

Chapter 5. CONCLUSIONS, RECOMMENDATIONS AND FURTHER RESEARCH QUESTIONS.

The motivation of this thesis had an additional interest after the sharp drop in oil prices in late 2014. Everyone started to regard the shale energy projects in general with less confidence, but specially the ones in marginal areas such as Argentina. This additional pressure was translated in a specific identification of logistics and transportation costs as key components for cost reduction, not just to be more efficient, but even to make VM a viable project.

In this regard, understanding the dynamics of the interaction between the shale production and the transportation and logistics systems through the CLIOS Process was crucial together with the implementation of a methodology that contributes to the understanding of the problem of simultaneous incentives between private companies and the public sector in this infrastructure financing problem.

5.1. SUMMARY OF THE CONTEXT

This section provides a summary of the main ideas regarding the context of shale energy in the word and in particular in Argentina:

i. **In a world where energy consumption is strongly increasing driven by emerging countries, shale energy resources will increase in relative importance.**

As was described in Chapter 1, the world energy consumption is expected to increase more than 58% between 2008 and 2035 (EIA 2011b), mainly driven by emerging economies such as China and India. Oil and gas are still the main sources of energy in the world and are particularly crucial for some sectors (e.g. for transportation), and their demand is expected to increase over 40% in the next 20 years.

Revisiting the ideas presented in Section 2.1.1, the shale oil and gas are resources trapped in the source rocks (this was known even from the beginning of the oil industry) but were not technically or economically possible to extract. These resources are indeed called "non-conventional" because of the way they are extracted, in opposition to the "conventional". With the joint implementation of two technologies (hydraulic fracturing and horizontal drilling) that were already being used in conventional exploitations for decades together with some technological improvements, it became economically efficient to extract these resources in the mid-2000s, creating a real boom in the US oil and gas industry, and even producing a spillover effect over the rest of the economy (Section 2.2.4).

In this context, the worldwide importance of shale resources is expected to increase, achieving an estimated market share of 12% of the total liquid fossil fuels produced worldwide in 2035, according to the EIA. In fact some observers attribute the decision of surplus production from OPEC countries that massively dropped prices in the second half of 2014 to be in retaliation to the increasing importance of shale oil and shale gas production in the US, as a way to push shale companies out of business (The Economist 2014 b).

ii. The main importance of shale energy resources is related to changes in geopolitical positions for specific countries.

By analyzing the total amount of reserves of OPEC countries and specially their very low costs of extraction–the marginal cost of extraction of Saudi Arabia's best quality oil is estimated in a range between $10 to $20 per barrel (Reuters 2014b)–it is clear that the main importance of the shale energy development will be in changing the geopolitical consideration for specific countries, but not producing a massive increase in worldwide oil and gas reserves, as was observed in Section 2.1.2.

The main example of this is the US where the shale production allowed big reductions in oil imports by replacing it with local shale resources (Section 2.1.1). In the overall worldwide oil production numbers shale could be considered to be marginal (around 12% by 2035, as was seen in Chapter 1) but in geopolitics of the US, it is a big change in the negotiation of power between nations. In fact, as Carlson (2014) states, the US energy security issue has been in the public debate for decades with different views in each presidency and shale resources certainly brought a new argument into this debate over the last decade.

Argentine shale resources will required large and continued investments that at the end could provide a secure domestic source of energy, opening new possibilities for the country in the future by providing energy independence and changing its geopolitical position, together with the possibility of exporting its energy surplus. But, Argentina will not become Saudi Arabia, in the sense of having a huge amount of resources at a very low marginal cost.

As was presented in Section 2.1.3, the change in the energy perspectives will also provide a new industrial outlook with the possibility of having cheap energy that could make other industries more competitive, making VM a game-changer for Argentina's future perspectives.

The energy self sufficiency is also a topic of debate in Argentina since mid-1900s and is very related to the oil nationalism, as was described in Section 2.1.3.1. Different presidents had opinions on this topic and especially this was a main issue of the presidential campaign of 1958, when President Arturo Frondizi was elected and the main conventional oil fields were put in production in an attempt to decrease the large amount of energy imports of the country.

Today the situation is similar: the big energy deficit of the country described in Section 2.1.3.4, pushes this topic into the national agenda, and the shale energy resources have brought a new perspective for the energy industry, and even the country. In fact YPF's nationalization Law No 26,741 approved by Argentine Congress on May 3, 2012 states in its first article: "Declared of national public interest and priority objective of Argentina to achieve self-sufficiency in oil and exploration, production, processing, transportation and sale of hydrocarbons, to ensure economic growth with social equity, job creation, increase competitiveness of various economic sectors and equitable and sustainable growth of the provinces and regions." Since this partial nationalization (51% of shares), YPF has taken the lead in the development of VM, as mentioned in Section 2.1.3.2, and has steadily increased its production of oil (+10%) and gas (+30.8%[34]). By March 2015, approximately 9% of YPF's oil and gas production was coming from shale and tight formations (YPF Investor Presentation–March2015), showing that VM is already underway.

5.2. FINDINGS

Considering the summary of the context provided before, this section provides the key findings os this work, from the general to the specific:

I. Undoubtedly the development of shale resources in the US was immersed in certain special conditions that made it extremely favorable to generate the so-called *shale-boom* (Section 2.1.2), to the extent that some authors argue that these conditions are irreproducible in the short run outside the US. However, there could exist "functional equivalents" that could potentially allow a large shale development abroad, like the one that Argentina is trying to carry out.

Starting with the ideas presented by Maugeri (2013), in Section 2.1.2 seven reasons why shale development outside the US will be "improbable" in this decade were presented.

[34] It includes the increase of production due to the acquisition of Apache assets in Argentina in 2014 (YPF Investor Presentation–March2015)

These ideas range from regulatory issues (i.e. property rights) to actual physical issues (i.e. water availability), through institutional issues (i.e. quality of the financial system). Clearly the authors who hold these ideas argue, with reason, that in fact the shale phenomenon outside the US is still very incipient (in 2013, in the US and Canada 15,000 wells were drilled, while in Argentina, the second in the ranking, they were just over 200, as was shown in Section 2.1.2).

However, in Section 2.1.4 the author, using some ideas presented in the literature, has been able to analyze and make an argument on each of these reasons for the specific context of Argentina, verifying that there may exist certain "functional equivalents" that could allow development of shale industry, even if probably with slower pace and smaller size than the US shale boom. Some of these "equivalent" refer to changes in methodologies or ways of contracting, but others are simply a verification of equivalent conditions between the main US shale plays and VM.

II. The history of the Argentine oil industry shows–along with the US shale boom benchmark–the close relationship between logistic infrastructure and oil project development.

During the early years of oil exploitation in Argentina, in the 1880s, several private projects failed due to lack of adequate logistic infrastructure, as was mentioned in Section 2.1.3.1. At the same time, the current US shale boom showed that the availability of efficient transportation infrastructure was crucial to accomplish the development (Section 2.2.1). Today, the same concerns are highlighted about the incipient development of VM. The transportation and logistics cost are main drivers of the total exploitation costs and are the focus of attention of private companies, especially YPF, as was presented in the initial conclusions of Chapter 2.

As was described in Chapter 2, the shale energy developments require the use of extraction technologies that are very intensive in the use of inputs. The main supplies required are water, proppant agents (e.g. sand), pipes, equipment, different construction materials and other chemical products needed for the hydraulic fracturing and the horizontal drilling. This intensity in the use of inputs is driving the demand for transportation services and the logistic infrastructure related in Argentina. As was also described in Chapter 2, since the main shale projects are located in areas where conventional exploitation has been occurring for more than sixty years, there are some advantages: for example there is spare capacity in the outbound logistics infrastructure (pipelines) in the short term since the decline of conventional production of oil and gas over the last decade left the capacity for the new incipient unconventional production.

In the context of the sharp decline in oil prices since mid-2014, the logistic efficiency is now the focus of attention to reduce operational costs and with it, the discussion about how the required infrastructure should be developed. YPF, as the main driver of the VM development, considers this issue a key point for the future development in the 2014 and 2015 investor's presentations. Since YPF is vertically integrated and the number of stakeholders in the shale oil and gas industry is still very small, the decision power of the actors, including YPF, is particularly high, as was introduced in Section 3.3.

III. Logistic infrastructures commit large amounts of investments and are a long-term decision that allows an effective reduction in operational costs. The selection of the most efficient economic alternative is a relatively straightforward process but the definition of "who pays" for an infrastructure where the beneficiaries are very concentrated, is a different problem where issues like fairness and equity appear.

Because of the size of the investment required, the logistic infrastructure decisions are long-term and require an overall planning effort to achieve the best possible solution. Putting this together with the idea developed in the previous point II, the definition on how to finance infrastructure where the users are very concentrated is not trivial, as was discussed in Section 4.1. In the context of Argentina, a middle-income country with a significant portion of the population under the poverty line, the decision of how to allocate public resources is crucial and will have implications for other sectors that appear to be more vulnerable (for example health and education). Here, categorical statements seem to be less precise and issues of social justice appear together with private sector incentives to move forward to the socially optimal decision.

With the reduction of logistics costs, other interactions arise: the lower the marginal cost of production per well, the more production areas become economically feasible; this increases the total volume produced. Therefore, finding more efficient logistics solutions is also a production multiplier, which adds value to the sector and the economy as a whole.

The debate about how to finance better infrastructure is very broad, and is present in both developed and developing countries, but with obvious differences. Grigg (2010) says: "The quality of life and our future success in solving national problems will depend greatly on how effectively we develop and manage our infrastructure systems. In turn, these depend on both public sector management and private sector investment. Thus, investors, public sector managers, and policy makers have critical roles in forging new forms of public-private cooperation to make government efficient and responsive. As this cooperation strikes a balance between economic advancement, social equity, and environmental protection, it will create exciting new opportunities across the infrastructure sectors."

IV. Correct incentives for the private sector logistics decisions are crucial for the implementation of socially optimal alternatives.

Considering the importance of the private sector in the development of shale resources, it is crucial to understand the incentives in the selection of logistic alternatives in order to make efficient decisions that are in line with the social optimum. To understand these incentives, in Chapter 4 the author proposed the Simultaneous Economic-Financial Analysis Model (SEFAM) that allows the decision maker to realize to what extent the government intervention is required to align the private incentives toward the most efficient logistic alternative. SEFAM seek to provide the decision maker with useful information for a negotiation process that intent to lead to the social optimum using known methods as the economic and financial evaluations.

In this regard, the role of government can be multiple and wide-ranging, as was discussed during the implementation of the VM Research Case in Section 4.3. The author believes that it is important to ensure that incentives are correct so that the sum of individual decisions is aligned to the common good. This goes beyond achieving a Public–Private Partnership (PPP) or similar structures because these are just ways to achieve the result; the important thing is that the environment for the decision makers facilitates the optimal solution. That's why the author supports solutions in which the private sector and the government are clear about their roles independently, and not just because of a formal circumstantial construction (PPP). This proper constructive environment is what can enable a long-term development, as was presented in the conclusion of Chapter 4 (Section 4.5).

V. In the VM research case, the role of railroads is crucial to achieve operational efficiency together with social equity and environmental protection. But its implementation requires government support in helping mitigate the risk of a large investment with a long repayment period.

Given the characteristics of the transportation of supplies for VM (large volumes and long distances on flat topography) makes railroad technology very competitive, and especially beneficial when taking into account the "saved" externalities (e.g. environment) in comparison with trucking alternatives, as can be seen from the results of the application of the Global Economic Assessment of SEFAM into the VM Research Case in Section 4.4.2.

However the results of this research case show that the incentives for private companies acting in isolation are not aligned with the implementation of rail alternatives (Section 4.2.2). The simplest explanation is that given the high level of funds required by the railway investments with long payback periods, the risk perceived by investors is large enough that private companies prefer to use trucking alternatives that have a lower risk although higher operating (and social) costs. This distortion in incentives, as mentioned previously, may be corrected in many different ways. In the research case, we chose two families of solutions: one in which the government makes all capital investments without charging the private sector for the use of infrastructure (analogous to the case of use of highways) and the other in which the government acts as lender (or even as an Infrastructure Manager in an Open Access framework) by making the investments and charging private companies a fee for the use of infrastructure to (Section 4.4.3). Therefore, there are a variety of ways to correct incentives. Choosing which may be considered fairer is a decision of each society, represented by its government.

In the Argentine case, another question also becomes relevant: which government should have that role of supporting the development of infrastructure: national or provincial? Since the provinces are the owners of the natural resources because of the federal conception of the country (Article 124 of the Argentine Constitution), as was presented in Section 2.1.3.1, they charge royalties for the oil and gas production; in the case of VM this production is almost entirely in Neuquén. However, most of the required infrastructure is in other provinces (in the research case: Buenos Aires, La Pampa and Rio Negro). Additionally, the new hydrocarbons law passed in 2014 (commented on in Section 2.1.3.3) mention that the national government will invest in infrastructure a percentage to be determined in the oil productive provinces, funded by the national treasury. All this suggests that certainly a discussion is needed of how to plan and finance the logistic infrastructure required by VM in Argentina, so SEFAM can be a useful tool for this analysis.

VI. For the VM case, it was verified that the only intervention of the government as a lender could be enough to make the railroad alternatives (that are socially optimal solutions) to be also the cheapest for the private sector.

The application of SEFAM showed that just providing support as lender with lower interest rate to fund the construction, could be enough to transform the railway alternative into the cheapest for the private sector, without requiring the commitment of large public funds that could be used for other critical sectors (e.g. education or health). As was mentioned in Section 4.5, in general in developing countries and in particular in Argentina, the government is the most creditworthy entity so is able to borrow at the lowest rates and in most cases is the only entity able to borrow very large amount of funds, making crucial its participation in infrastructure projects to make them financially viable.

VII. The Open Access framework of the Argentine railroad system that will be probably implemented in the following years could incentivize the sub-alternatives presented in this thesis.

The sub-alternatives B3.1 generated by the implementation of SEFAM in the VM Research Case could also be thought of as Open Access situations in which the government makes the investment and charges the private operators a toll, equivalent to the cost of infrastructure plus interest to compensate for the financing cost. This framework should ensure fair competition for the use of the infrastructure to guarantee the pursuit of efficiency for all current or future operators.

In March 2015, the Argentine Congress approved (with almost complete support from all political parties) a new law that allows Open Access to the railroad infrastructure. This could anticipate that finally, after several years of uncertainty, freight railroad transportation will have this regulatory system. However, the success of this new system requires a new regulation that should be professionally developed and implemented to provide a clear control of the responsibilities of each actor, that it is still pending.

VIII. The implementation of a railroad operation company owned by a consortium of oil and gas producers, emulating the current management structure of the pipeline's operation companies in Argentina, could achieve good operational efficiency and market oriented behavior.

For the case of the main pipelines in Argentina, as was detailed in Section 2.1.3.4, a consortium of oil and gas producers controls the operating company, by owning shares. This operational model in which the final stakeholder is also part of the operating company in solidarity can be an interesting strategy to achieve good operational efficiency and very market oriented behavior of the transportation company. At the same time, the oil and gas producers are interested in having decision power over the transportation company to avoid monopolistic behavior and control its costs.

As a counterpoint, it is important to establish clear rules of fair competition for eventual access to rail infrastructure to avoid discouraging the participation of new VM producers not included in the railway operator consortium, limiting the monopolistic behavior.

5.3. PROBLEM FORMULATION AND METHODOLOGICAL APPROACH

The methodological framework of this thesis was based on the formulation of a general question—how should the logistics and transportation infrastructure related to shale developments, in particular VM, be planned and funded?—which was expanded with the generation of three clusters with more detailed questions, which allowed us to tackle the problem from different angles.

In this instance, after analyzing the systems involved, their main actors with their interrelationships, and finally having presented an analytical model that was implemented in a research case in VM to evaluate different alternatives, we can move forward to respond to each cluster of questions.

QUESTION CLUSTER 1: TRANSPORTATION AND LOGISTICS REQUIREMENTS

The infrastructure investments are long-term and expensive decisions for society. What is driving the demand for new infrastructure capacity for shale energy developments in Argentina? What are the bundles of strategic alternatives for providing this transportation capacity? Which institutional actors have influence over the implementation of these alternatives?

The main driver for the demand of new infrastructure capacity is the input requirements that are an intrinsic characteristic of the technologies involved in the shale energy exploitations. The high volumes together with the long distances from the production point make the input logistics a critical point in the drilling cost structure. These logistic requirements, as were presented in Section 2.1.1, are completely different from those in conventional oil and gas exploitation. So, even though in the Neuquén Basin there was conventional oil production for decades, the inbound logistic and transportation infrastructure in place is not able to handle the capacity required by a massive shale development (Section 2.2.2). The situation for the outbound logistics is different, since in this case the decrease in O&G conventional production over the last decade left empty capacity on the pipelines to accommodate this new shale oil and shale gas to be produced, at least in the short-term.

The bundles of strategic alternatives developed in Chapter 3 through the implementation of the CLIOS Process were presented in Section 3.4 following a 3-level classification. The first level was the transportation mode; the second was how the infrastructure capital investments are funded and the third was related to the source of funding for maintenance. These bundles were then used in the application of SEFAM in the VM Research Case in Chapter 4 to achieve the conclusions presented in Section 4.5.

YPF is the leading actor in the development of VM, showing its complex interaction with the national and provincial governments where: on one hand, these two governments are owners of a portion of YPF's shares (for which they receive dividends), but on the other they are responsible for regulating, controlling and generating exploration and exploitation permits. The CLIOS Representation developed in Section 3.2 shows the different actors in the institutional sphere and helps to understand the influence of institutional actors over the implementation of these bundles of logistic strategic alternatives.

Others oil and gas producers were presented along with logistic sector actors (railroad and trucking operator companies), together with the oil and gas (O&G) industry suppliers that in some cases will be in charge of taking some logistic decisions. In the overall picture, two more actors were included: the Argentine society, as the perspective of the citizenship in particular due to the social an environmental impacts, and others shale producers countries that could eventually be affected by the production decisions on the VM shale resources production system in a competing oil international market.

As was mentioned, the different actors in the institutional sphere have different levels of influence in each of the bundles of strategic alternatives, so that incentives may not be aligned or balanced.

QUESTION CLUSTER 2: ANALYSIS OF BUNDLES OF STRATEGIC ALTERNATIVES IN A CLIOS SYSTEM

How can we analyze these bundles of strategic alternatives taking into account the particular interests of each of the actors? How should we design the infrastructure? How can we generate useful information for the discussions on infrastructure finance that allows the actors to work toward an optimal decision for the country? How does uncertainty affect the strategies of the actors?

The structure of the Simultaneous Economic-Financial Analysis Model (SEFAM) presented in Chapter 4 analyzes the system from different perspectives, including those of each actor. This methodology leads to the definition and generation of the useful information required in a prospective negotiation between the actors, in the attempt to reach the optimal solution for the society. SEFAM uses known methods as BCA and financial evaluation combined with a fiscal analysis for doing this.

SEFAM was applied to the VM research case in Section 4.3 to analyze the bundles of strategic alternatives defined, analyzing the divergence between the social and private cost when only the financial (cash flow) cost of each alternatives were considered. The analysis of the evaluation of alternatives from a private perspective seeks to bring a new insight that goes beyond the conventional Benefit-Cost Analysis trying to understand the taxation and incentives problem, specially important in a middle-income country like Argentina, where the allocation of public funds is crucial.

In particular, the design of the infrastructure should take into account the social optimum alternative and the best way in which the public and private sector should interact to reach it.

Regarding uncertainty, Chapter 2 described the regulatory uncertainty facing the railroad industry produced by changes in the regulatory structure that may affect the marginal decision between modes.

QUESTION CLUSTER 3: PUBLIC AND PRIVATE PARTICIPATION

If the private sector should lead the role of financing infrastructure development, what considerations of planning and regulation should be addressed? What should the framework be to ensure fair competition for the use of the infrastructure to guarantee the pursuit of efficiency for all current or future stakeholders? What should the design of the institutional architecture be?

Bearing in mind that for new shale oil and gas new exploitations the private sector is going to have a leading role in the development of logistic infrastructure, basic considerations of planning and regulation structure should be addressed, as described in Section 3.3 for the railroad alternatives. This regulation, for example related to the Open Access of railroad infrastructure in the VM Research Case, has to assure a fair competition of current and future oil producers in order to guarantee the pursuit of efficiency.

The institutional architecture will have to take into account this double effect of giving incentives to the private sector, to allow and incentivize private investment to the implementation of socially optimal alternative, but at the same time will have to address the fairness problem between producers. Also will have to consider the real-world distortions in the private decision process that produce unfair competition between modes.

As was described in the conclusion section of Chapter 4, an interesting solution for the framework to implement the railroad alternatives is the formation of a consortium of oil and gas producers that controls the operating company by owning shares, emulating the today pipeline operation model in Argentina. This operational model in which the final stakeholder is also part of the operating company in solidarity can be an interesting strategy to achieve good operational efficiency and very market oriented behavior of the transportation company. At the same time, the oil and gas producers would be interested in having decision power over the transportation company to avoid monopolistic behavior and control its costs. As was also mentioned in Section 4.5, it is important to establish clear rules of fair competition for eventual access to rail infrastructure to avoid discouraging the participation of new VM producers not included in the railway operator consortium.

In all cases, the implementation design of new regulations should be professionally planned and implemented to be successful; examples of positive cases in other countries should be considered.

5.4. Conclusions and Recommendations

The goal of this thesis is to state new questions that help understand the whole picture of the problem, and specially to understand the different perspectives. This thesis seeks to open the discussion about how to conceptualize the required logistic infrastructure and even to start thinking how we should plan the overall development of VM, as a potential game changer for the country. By applying SEFAM to the VM Research Case, same important findings were presented in Section 5.2 related to the best strategy to align the private sector incentives to the implementation of railroad alternatives that are socially better than the trucking alternatives.

Since the objective of an academic thesis can be to open the social debate of an important topic, the conclusions of this thesis are mainly framed as trade-off analyses with questions for further studies.

Keeping this in mind and based on the findings presented in Section 5.2, the author invites the reader to consider the following conclusions:

- The successful development of shale energy is closely related to achieving efficient logistics, and in this sense the logistical decisions of the private sector are crucial. Understanding the way the O&G private sector makes decisions is essential to plan and fund new infrastructure.
- In Argentina in general, the "planning" activities are undervalued and are seen in many cases as nuisance activities that produce delays in the decision process, but this deficit is more critical in the context of VM. As was presented in this thesis, planning is definitely crucial to making the right long-term decisions and achieving the development of VM and the country.
- The Argentine engineering sector should identify its critical role in this planning process to avoid short–term biased decisions. For this, the epigraph in the first pages of this thesis of President Arturo Frondizi should summarize the calling of the Argentine engineers: to work for the development of the country immersed in reality.
- VM has the potential to be an example of a collective project that could improve the quality of the Argentine institutions and the decision making process in particular. Even if this idea is certainly ambitious, this thesis showed an example of a logistic decision process that could be improved by considering different perspectives simultaneously.
- Regarding Argentine logistics, there are many other sub sectors of the economy with serious problems of competitiveness as a result of the high transportation and logistics costs; the clearest example is the agricultural sector that, in terms of production, is extremely competitive worldwide, but loses this efficiency because of logistics and transportation deficiencies all over the country. New solutions applied to VM logistic infrastructure could help in solving other key problems of the Argentine logistics sector that are still pending. The framework of the model introduced in this thesis (SEFAM) has the capability to be adapted to other infrastructure decisions beyond VM. The efficient development of VM must be an example that is then applied to the rest of the Argentine logistics system.
- One of the key points that this thesis highlights is the need to have regulatory schemes for the transport sector that are clear, fair and preserved over time. In this regard, the example of the railway sector is the most obvious: the discoordination of actors, the overlapping roles and the lack of a clear definition of a railway policy in the last decades has led to a current unstable situation that must be corrected. The debate over the best freight railway policy is certainly open and is the focus of public discussion. This debate should be

professionally driven in order to find the best solution for society that allows long-term investments.

- VM has the potential to ultimately be a countrywide game-changer not only improving the economic and social structure of the country, but especially being the "excuse" to increase the perceived value of coordinated planning, improving the systems involved particularly the Argentine logistics system.

5.5. FURTHER QUESTIONS AND FINAL THOUGHTS

The development of shale energy in Argentina presents a number of challenges (i.e. technical, economic, environmental and institutional issues) that will certainly require a major effort to resolve individually. However, as a geopolitically strategic and game-changing project for Argentina, it will have a much **broader impact** on the country, the oil companies and society, as was mentioned. VM is a once-in-a-generation opportunity in the history of Argentina; YPF is emerging as the natural leader of this development.

It would therefore be interesting to apply the complete CLIOS Process, including the 12 steps of the 3 stages, to analyze the entire VM production system (not only logistics), considering that the overall bundle of strategic alternatives reflects the largest possible "pie." From there, new specific CLIOS processes could be defined to analyze the opportunities from the perspective of individual actors. One example could be from the perspective of YPF, creating a $CLIOS_{YPF}$ Process. This idea follows a reasoning from the general to the particular: we start thinking about the problem in terms of overall efficiency and effectiveness from the viewpoint of Argentina (CLIOS Process) and then we focus on specific strategies for a particular actor (i.e. $CLIOS_{YPF}$ Process).

Another area for future research could be the application of SEFAM to other important deficiencies of the Argentine logistic system, such as transport of agricultural products[35]. This is certainly a critical issue for the overall productivity of the country that should be analyzed in the short term. However, clearly the systems involved are different from the VM case: in the agriculture sector, the productive private sector is much more dispersed and decision-making mechanisms are more fragmented. It would therefore be interesting to apply an analysis similar to the one developed in this thesis to this problem in order to make a comparative evaluation and draw some comprehensive conclusions.

[35] FAO United Nations website retrieved on May 2015: http://www.fao.org/agronoticias/agro-noticias/detalle/en/c/270908/

Undoubtedly Argentina has a potentially bright future, but to make it possible, a vision of where we want to go as a country is needed. In that sense, raising questions about how we want to plan the development of VM can be an exercise to help us improve on how we make decisions as a society in general.

This idea that VM could bring to the Argentines the opportunity for discussing better planning, also mentioned by Barrera (2014) in her thesis, opens the discussion beyond the problem of infrastructure, and gives us the opportunity to think of a better future. This planning vision is what the fathers of Argentina had. Beyond thinking, they were able to *execute* it, making Argentina one of the world's most developed countries in the early twentieth century. And paradoxically we can find an example of this difference in planning strategies between then and today in the same construction of the Bahia Blanca-Neuquén railway line that goes into VM. In 1896, a strong interaction between public and private sector managed to build over 500 kilometers of railway in a remote area in less than 36 months in an attempt to counter an external threat. Today, over a century later, with very best technology and resources available, this infrastructure is mainly the same without a real policy of long-term development. It is our duty to find ways of development that will lead to progress again.

VM is certainly an opportunity, and in this sense the author urges us to think ambitiously and find spaces where these issues are openly discussed in pursuit of a better future and the welfare for the country. In this sense there are fundamental topics that still need to be discussed by the Argentine society: from deciding how we will manage resources generated by VM to avoid the resource curse[36] to how we should regulate and mitigate environmental risks. Moving towards an advanced society means we have to achieve consensus on basic issues that goes beyond the political moment and seek to find common agendas that transcend individuals. Definitely VM is the great challenge of our generation; we must fulfill our commitment.

Having reached this point, the author would like to thank readers for considering the ideas raised by this thesis. This thesis represents a first attempt to consider the complex questions raised by the relationship between infrastructure planning and shale energy project development in Argentina; the author would welcome further discussion.

[36] According to Barrera (2014): "The abundance of natural, non-renewable resources has been vastly studied in economic literature and in policy discussions under the resource curse theory, understood as the negative effect of natural resource dependence on economic development and growth."

A) APPENDIX

As a detail mentioned in Section 2.1.3.4, below is provided the full list of companies involved in the O&G upstream sector of the Neuquén Basin, including its volume of production, its market share within the basin and the domestic production.

Table A-1 Main players in the Neuquén Basin for oil and natural gas production (Author with data from ASoE)

	2014 Oil Production (m3)	Over total country oil production	Over basin oil production
NEUQUINA			
YPF S.A.	5,462,460	17.7%	44%
PLUSPETROL S.A.	2,122,390	6.9%	17%
CHEVRON ARGENTINA S.R.L.	1,160,769	3.8%	9%
PETROBRAS ARGENTINA S.A.	1,007,184	3.3%	8%
PETROLERA ENTRE LOMAS S.A.	721,292	2.3%	6%
PETROQUIMICA COMODORO RIVADAVIA S.A.	390,964	1.3%	3%
APACHE ENERGIA ARGENTINA S.R.L.	319,440	1.0%	3%
TECPETROL S.A.	163,019	0.5%	1%
TOTAL AUSTRAL S.A.	156,428	0.5%	1%
MEDANITO S.A.	122,543	0.4%	1%
PETROLEOS SUDAMERICANOS S.A.	85,727	0.3%	1%
ROCH S.A.	83,073	0.3%	1%
CENTRAL INTERNATIONAL CORPORATION (SUCURSAL ARGENTINA)	79,300	0.3%	1%
AMERICAS PETROGAS ARGENTINA S.A.	71,623	0.2%	1%
OILSTONE ENERGIA S.A.	70,750	0.2%	1%
PETROLIFERA PETROLEUM (AMERICAS) LTD. (SUCURSAL ARGENTINA)	52,968	0.2%	0%
SAN JORGE PETROLEUM S.A.	37,905	0.1%	0%
CAPEX S.A.	36,947	0.1%	0%
PAN AMERICAN ENERGY (SUCURSAL ARGENTINA) LLC	35,009	0.1%	0%
O&G DEVELOPMENTS LTD S.A.	31,498	0.1%	0%
APACHE PETROLERA ARGENTINA S.A.	27,480	0.1%	0%
PETROLERA EL TREBOL S.A.	23,251	0.1%	0%
EXXONMOBIL EXPLORATION ARGENTINA S.R.L.	22,671	0.1%	0%
GRECOIL y CIA. S.R.L.	10,177	0.0%	0%
ENERGIAL S.A.	5,067	0.0%	0%
PETROLERA DEL COMAHUE S.A.	3,228	0.0%	0%
COMPAÑÍA GENERAL DE COMBUSTIBLES S.A.	3,180	0.0%	0%
GAS Y PETROLEO DEL NEUQUEN S.A.	2,567	0.0%	0%
INGENIERIA SIMA S.A.	1,394	0.0%	0%
WINTERSHALL ENERGIA S.A.	1,123	0.0%	0%
PETROLERA PAMPA S.A.	81	0.0%	0%
ARGENTA ENERGIA S.A.	71	0.0%	0%
GEOPARK ARGENTINA LTD. (SUCURSAL ARGENTINA)	51	0.0%	0%
ARPETROL ARGENTINA S.A.	0	0.0%	0%
MISAHAR ARGENTINA S.A.	0	0.0%	0%
OIL M&S S.A.	0	0.0%	0%
KILWER S.A.	0	0.0%	0%
MADALENA AUSTRAL S.A.	0	0.0%	0%
PETROLERA PIEDRA DEL AGUILA S.A.	0	0.0%	0%
ALIANZA PETROLERA ARGENTINA S.A.			
ENARSA ENERGIA ARGENTINA S.A.			
ENERGICON S.A.			
OCCIDENTAL ARGENTINA EXPLORATION AND PRODUCTION, INC.			
PETRO ANDINA RESOURCES LTD.			
SIMA ENERGY S.A.			
SINOPEC ARGENTINA EXPLORATION AND PRODUCTION, INC.			

	2014 Gas Production (m3)	Over total country gas production	Over basin gas production
NEUQUINA			
YPF S.A.	**10,543,151**	**25.4%**	**45%**
TOTAL AUSTRAL S.A.	**5,209,171**	**12.6%**	**22%**
PETROBRAS ARGENTINA S.A.	**2,214,270**	**5.3%**	**10%**
APACHE ENERGIA ARGENTINA S.R.L.	1,388,175	3.3%	6%
PLUSPETROL S.A.	1,096,593	2.6%	5%
CAPEX S.A.	503,587	1.2%	2%
PETROLERA ENTRE LOMAS S.A.	480,008	1.2%	2%
PAN AMERICAN ENERGY (SUCURSAL ARGENTINA) LLC	427,665	1.0%	2%
TECPETROL S.A.	399,213	1.0%	2%
PETROQUIMICA COMODORO RIVADAVIA S.A.	295,368	0.7%	1%
CHEVRON ARGENTINA S.R.L.	238,106	0.6%	1%
MEDANITO S.A.	157,065	0.4%	1%
PETROLIFERA PETROLEUM (AMERICAS) LTD. (SUCURSAL ARGENTINA)	62,585	0.2%	0%
OILSTONE ENERGIA S.A.	56,055	0.1%	0%
SAN JORGE PETROLEUM S.A.	41,741	0.1%	0%
AMERICAS PETROGAS ARGENTINA S.A.	26,077	0.1%	0%
ROCH S.A.	21,144	0.1%	0%
APACHE PETROLERA ARGENTINA S.A.	13,918	0.0%	0%
COMPAÑÍA GENERAL DE COMBUSTIBLES S.A.	8,334	0.0%	0%
PETROLEOS SUDAMERICANOS S.A.	8,298	0.0%	0%
CENTRAL INTERNATIONAL CORPORATION (SUCURSAL ARGENTINA)	8,139	0.0%	0%
EXXONMOBIL EXPLORATION ARGENTINA S.R.L.	6,924	0.0%	0%
O&G DEVELOPMENTS LTD S.A.	4,658	0.0%	0%
GRECOIL y CIA. S.R.L.	2,091	0.0%	0%
WINTERSHALL ENERGIA S.A.	1,933	0.0%	0%
GAS Y PETROLEO DEL NEUQUEN S.A.	1,879	0.0%	0%
PETROLERA EL TREBOL S.A.	796	0.0%	0%
ARGENTA ENERGIA S.A.	57	0.0%	0%
ARPETROL ARGENTINA S.A.	0	0.0%	0%
ENERGIAL S.A.	0	0.0%	0%
GEOPARK ARGENTINA LTD. (SUCURSAL ARGENTINA)	0	0.0%	0%
INGENIERIA SIMA S.A.	0	0.0%	0%
KILWER S.A.	0	0.0%	0%
MADALENA AUSTRAL S.A.	0	0.0%	0%
MISAHAR ARGENTINA S.A.	0	0.0%	0%
OIL M&S S.A.	0	0.0%	0%
PETROLERA DEL COMAHUE S.A.	0	0.0%	0%
PETROLERA PAMPA S.A.	0	0.0%	0%
PETROLERA PIEDRA DEL AGUILA S.A.	0	0.0%	0%

To show the numerical results of comparing a curve of conventional gas production vs. tight, a comparative graph is included below, following the ideas presented in Section 2.1.1.

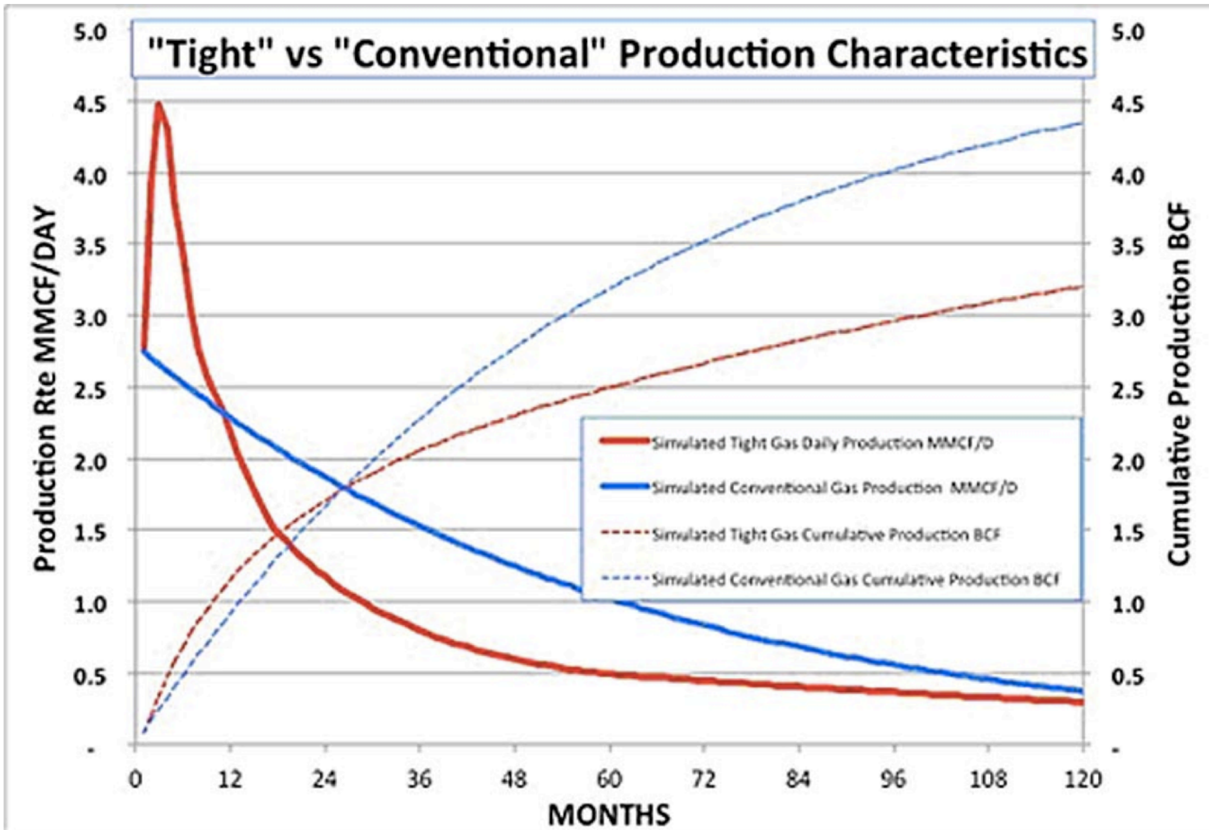


Figure A-1 Tight vs. conventional production curves (Barchana Advisory[37])

To the readers interested in the detailed implementation of SEFAM into the East-West VM supply corridor, below we presented the application of the methodology described in the Chapter 20 of the Highway Capacity Manual (HCM 2000) for computing the "Number of additional hours in traffic due to congestion produced by VM traffic". Then, in the following pages we included the full cash flow of every component of the model:

- **A.2) Global Economic Assessment–Project cash flow**
- **A.3) Financial evaluation–Project cash flow**
- **A.4) Fiscal Analysis**

[37]Website retrieved on April 2, 2015: http://www.barchanadvisory.com/news03.htm

Table A-2 Assessment of congestion impact: application methodology Chapter 20 of HCM (2000)

	Highways	RN 22
	Weighted AADT	3893
	% of Trucks	43.5%
	Length	635
	Demand volume for the full peak hour (veh/h) V	959
	Directional distribution	0.5
	Peak-hour factor	1.0
	% recreational vehicles, PR	0%
	% no-passing zones	80%
	Terrain	Plain
	Grade adjustment factor, f_G (Exhibit 20-7)	1.0
	Passenger-car equivalent for trucks, obtained from Exhibit 20-9, E_T	1.2
	Passenger-car equivalent for KVs, obtained from Exhibit 20-9, E_R	1.0
	Heavy-vehicle adjustment factor, f_{HV} (Eq 20.4)	0.9
	Passenger-car equivalent flow rate for peak 15-min period (pc/h), v_p (Eq 20.3)	1042.4
	Base Free Flow Speed BFFS	106.3
	Adjustment for lane width and shoulder width, from (Exhibit 20-5) f_{LS}	7.5
	Adjustment for access points, from Exhibit 20-6, f_A (Exhibit 20-6)	16.0
	Estimated Free Flow Speed FFS (Eq 20.2)	82.8
	Adjustment for percentage of no-passing zones (see Exhibit 20-11) f_{NP}	3.6
	Average travel speed for both directions of travel combined (km/h) (Eq 20.5)	**66.3**
	Grade adjustment factor, f_G (Exhibit 20-8)	1.0
	Passenger-car equivalent for trucks, obtained from Exhibit 20-10, E_T	1.1
	Passenger-car equivalent for KVs, obtained from Exhibit 20-10, E_R	1.0
	Heavy-vehicle adjustment factor, f_{HV} (Eq 20.4)	1.0
	Passenger-car equivalent flow rate for peak 15-min period (pc/h), v_p (Eq 20.3)	1000.7
	Base percent time-spent-following for both directions of travel combined (use Equation 20-7) BPTSF	59%
	Adjustment for combined effect of directional distribution of traffic andpercentage of no-passing zones on average travel speed on two-way segments, $f_{d/np}$ (Exhibit 20-12)	6.7
	Percent time-spent-following, BPTS (BPTSF - fD/NP)	**65%**
Alternative A	**Additional trucks**	202
	New AADT	4095
	New % of trucks	46.3%
	New demand volume for the full peak hour (veh/h) V	979
	New heavy-vehicle adjustment factor, f_{HV} (Eq 20.4)	0.92
	New passenger-car equivalent flow rate for peak 15-min period (pc/h), v_p (Eq 20.3)	2115
	New average travel speed for both directions of travel combined (km/h) (Eq 20.5)	53
	New heavy-vehicle adjustment factor, f_{HV} (Eq 20.4)	1.0
	New passenger-car equivalent flow rate for peak 15-min period (pc/h), v_p (Eq 20.3)	1025
	Percent Time Spent Following (PTSF)	66%
	Number of additional hours in traffic due to congestion produced by VM traffic	**135,065**

Table A-3 Global Economic Assessment–Project cash flow (Author)

Alternative A	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
truck-km	41,033,472	41,033,472	41,033,472	41,033,472	41,033,472	41,033,472	41,033,472	41,033,472	41,033,472	41,033,472	41,033,472	41,033,472	41,033,472	41,033,472	41,033,472
ESAL produced	188,184	188,184	188,184	188,184	188,184	188,184	188,184	188,184	188,184	188,184	188,184	188,184	188,184	188,184	188,184
Infrastructure investment	0	0	0	USD 533,300,701											
Infrastructure Maintenance Cost	USD 5,333,007	USD 5,333,007	USD 5,333,007	USD 5,333,007	USD 5,333,007	USD 5,333,007	USD 5,333,007	USD 5,333,007	USD 5,333,007	USD 5,333,007	USD 5,333,007	USD 5,333,007	USD 5,333,007	USD 5,333,007	USD 5,333,007
Operational economic cost	USD 194,312,818	USD 194,312,818	USD 194,312,818	USD 194,312,818	USD 194,312,818	USD 194,312,818	USD 194,312,818	USD 194,312,818	USD 194,312,818	USD 194,312,818	USD 194,312,818	USD 194,312,818	USD 194,312,818	USD 194,312,818	USD 194,312,818
Congestion cost	USD 1,636,758	USD 1,636,758	USD 1,636,758	USD 1,636,758	USD 1,636,758	USD 1,636,758	USD 1,636,758	USD 1,636,758	USD 1,636,758	USD 1,636,758	USD 1,636,758	USD 1,636,758	USD 1,636,758	USD 1,636,758	USD 1,636,758
Accidents cost	USD 46,331,229	USD 46,331,229	USD 46,331,229	USD 46,331,229	USD 46,331,229	USD 46,331,229	USD 46,331,229	USD 46,331,229	USD 46,331,229	USD 46,331,229	USD 46,331,229	USD 46,331,229	USD 46,331,229	USD 46,331,229	USD 46,331,229
Greenhouse emissions cost	USD 258,222	USD 258,222	USD 258,222	USD 258,222	USD 258,222	USD 258,222	USD 258,222	USD 258,222	USD 258,222	USD 258,222	USD 258,222	USD 258,222	USD 258,222	USD 258,222	USD 258,222
Result	*USD 247,872,035*	*USD 247,872,035*	*USD 247,872,035*	*USD 781,172,736*	*USD 247,872,035*	*USD 247,872,035*	*USD 247,872,035*	*USD 247,872,035*	*USD 247,872,035*	*USD 247,872,035*	*USD 247,872,035*	*USD 247,872,035*	*USD 247,872,035*	*USD 247,872,035*	*USD 247,872,035*
NPV	**USD 2,027,145,077**														
Total volume transported in 15 years	15,000,000	ton													
$ current/tonne	135.1	USD/ton													

Alternative B	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
railcar-km	22,572,414	22,572,414	22,572,414	22,572,414	22,572,414	22,572,414	22,572,414	22,572,414	22,572,414	22,572,414	22,572,414	22,572,414	22,572,414	22,572,414	22,572,414
tonne-km	1,309,200,000	1,309,200,000	1,309,200,000	1,309,200,000	1,309,200,000	1,309,200,000	1,309,200,000	1,309,200,000	1,309,200,000	1,309,200,000	1,309,200,000	1,309,200,000	1,309,200,000	1,309,200,000	1,309,200,000
Gross Ton Km	1,805,793,103	1,805,793,103	1,805,793,103	1,805,793,103	1,805,793,103	1,805,793,103	1,805,793,103	1,805,793,103	1,805,793,103	1,805,793,103	1,805,793,103	1,805,793,103	1,805,793,103	1,805,793,103	1,805,793,103
Infrastructure investment	USD 514,594,629	0	0	0	0	0	0	0	0	0	0	0	0	0	-USD 154,378,389
Epropiation cost	USD 13,500,000														
Infrastructure Maintenance Cost	USD 0	USD 10,659,664	USD 10,659,664	USD 10,659,664	USD 10,659,664	USD 10,659,664	USD 10,659,664	USD 10,659,664	USD 10,659,664	USD 10,659,664	USD 10,659,664	USD 10,659,664	USD 10,659,664	USD 10,659,664	USD 10,659,664
Rolling Stock Investment	USD 23,260,000														
Operational cost	USD 194,312,818	USD 74,054,954	USD 74,054,954	USD 74,054,954	USD 74,054,954	USD 74,054,954	USD 74,054,954	USD 74,054,954	USD 74,054,954	USD 74,054,954	USD 74,054,954	USD 74,054,954	USD 74,054,954	USD 74,054,954	USD 74,054,954
Congestion cost	USD 1,636,758														
Accidents cost	USD 46,331,229.32	USD 3,487,050	USD 3,487,050.00	USD 3,487,050.00	USD 3,487,050.00	USD 3,487,050.00	USD 3,487,050.00	USD 3,487,050.00	USD 3,487,050.00	USD 3,487,050.00	USD 3,487,050.00	USD 3,487,050.00	USD 3,487,050.00	USD 3,487,050.00	USD 3,487,050.00
Greenhouse emissions cost	USD 258,222	USD 28,358	USD 28,358	USD 28,358	USD 28,358	USD 28,358	USD 28,358	USD 28,358	USD 28,358	USD 28,358	USD 28,358	USD 28,358	USD 28,358	USD 28,358	USD 28,358
Resultado	*USD 793,893,657*	*USD 88,230,026*	*USD 88,230,026*	*USD 88,230,026*	*USD 88,230,026*	*USD 88,230,026*	*USD 88,230,026*	*USD 88,230,026*	*USD 88,230,026*	*USD 88,230,026*	*USD 88,230,026*	*USD 88,230,026*	*USD 88,230,026*	*USD 88,230,026*	*-USD 66,148,362*
NPV	**USD 1,202,775,212**														
Total volume transported in 15 years	15,000,000	ton													
$ current/tonne	80.2	USD/ton													

Table A-4 Detailed financial evaluation–Projected cash flow (Author)

Alternative A1.1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Road capital investment cost	USD 0	USD 0	USD 0	USD 719,505,572	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0
Road maintenance cost	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056
Operational finantial cost	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931
Result	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 947,582,558*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*
NPV	**USD 1,745,030,196**														
Total volume transported in 15 years	15,000,000 ton														
$ current/tonne	116.3 USD/ton														

Alternative A2.1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Road maintenance cost	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056	USD 7,195,056
Operational finantial cost	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931
Result	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*	*USD 228,076,986*
NPV	**USD 1,333,650,550**														
Total volume transported in 15 years	15,000,000 ton														
$ current/tonne	88.9 USD/ton														

Alternative A2.2	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Operational finantial cost	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931	USD 220,881,931
Result	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*	*USD 220,881,931*
NPV	**USD 1,291,578,396**														
Total volume transported in 15 years	15,000,000 ton														
$ current/tonne	86.1 USD/ton														

Alternative B1.1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Infrastructure capital investment	USD 712,481,771	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	-USD 208,280,451
Infrastructure Maintenance Cost	USD 0	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545
Rolling Stock Investment	USD 31,381,357	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0
Rail operational cost	USD 0	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648
Road operational cost (1st year)	USD 220,881,931														
Result	*USD 964,745,058*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*-USD 93,987,259*
NPV	**USD 1,382,241,439**														
Total volume transported in 15 years	15,000,000 ton														
$ current/tonne	92.1 USD/ton														

Alternative B2.1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Infrastructure Maintenance Cost	USD 0	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545
Rolling Stock Investment	USD 31,381,357	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0
Rail operational cost	USD 0	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648
Road operational cost (1st year)	USD 220,881,931														
Result	*USD 252,263,287*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*	*USD 114,293,193*
NPV	**USD 788,288,592**														
Total volume transported in 15 years	15,000,000 ton														
$ current/tonne	52.6 USD/ton														

Alternative B2.2	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Rolling Stock Investment	USD 31,381,357	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0
Rail operational cost	USD 0	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648
Road operational cost (1st year)	USD 220,881,931														
Result	*USD 252,263,287*	*USD 99,911,648*	*USD 99,911,648*	*USD 99,911,648*	*USD 99,911,648*	*USD 99,911,648*	*USD 99,911,648*	*USD 99,911,648*	*USD 99,911,648*	*USD 99,911,648*	*USD 99,911,648*	*USD 99,911,648*	*USD 99,911,648*	*USD 99,911,648*	*USD 99,911,648*
NPV	**USD 716,700,069**														
Total volume transported in 15 years	15,000,000 ton														
$ current/tonne	47.8 USD/ton														

Gvnt investment interest rate	15%														
Alternative B3.1	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Infrastructure investment	USD 101,576,065	USD 101,576,065	USD 101,576,065	USD 101,576,065	USD 101,576,065	USD 101,576,065	USD 101,576,065	USD 101,576,065	USD 101,576,065	USD 101,576,065	USD 101,576,065	USD 101,576,065	USD 101,576,065	USD 101,576,065	USD 101,576,065
Infrastructure Maintenance Cost	USD 0	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545
Rolling Stock Investment	USD 31,381,357	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0
Rail operational cost	USD 0	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648
Road operational cost (1st year)	USD 220,881,931														
Result	*USD 353,839,353*	*USD 215,869,258*	*USD 215,869,258*	*USD 215,869,258*	*USD 215,869,258*	*USD 215,869,258*	*USD 215,869,258*	*USD 215,869,258*	*USD 215,869,258*	*USD 215,869,258*	*USD 215,869,258*	*USD 215,869,258*	*USD 215,869,258*	*USD 215,869,258*	*USD 215,869,258*
NPV	**USD 1,382,241,439**														
Total volume transported in 15 years	15,000,000	ton													
$ current/tonne	92.1	USD/ton													

Gvnt investment interest rate	10%	USD 597,850,017	$597,850,016.53	USD 0											
Alternative B3.1	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Infrastructure investment	USD 78,601,600	USD 78,601,600	USD 78,601,600	USD 78,601,600	USD 78,601,600	USD 78,601,600	USD 78,601,600	USD 78,601,600	USD 78,601,600	USD 78,601,600	USD 78,601,600	USD 78,601,600	USD 78,601,600	USD 78,601,600	USD 78,601,600
Infrastructure Maintenance Cost	USD 0	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545
Rolling Stock Investment	USD 31,381,357														
Rail operational cost	USD 0	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648
Road operational cost (1st year)	USD 220,881,931														
Result	*USD 330,864,887*	*USD 192,894,792*	*USD 192,894,792*	*USD 192,894,792*	*USD 192,894,792*	*USD 192,894,792*	*USD 192,894,792*	*USD 192,894,792*	*USD 192,894,792*	*USD 192,894,792*	*USD 192,894,792*	*USD 192,894,792*	*USD 192,894,792*	*USD 192,894,792*	*USD 192,894,792*
NPV	**USD 1,247,901,236**														
Total volume transported in 15 years	15,000,000	ton													
$ current/tonne	83.2	USD/ton													

Gvnt investment interest rate	8.75%	USD 595,970,941	$595,970,940.96	USD 0											
Alternative B3.1	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Infrastructure investment	USD 72,847,795	USD 72,847,795	USD 72,847,795	USD 72,847,795	USD 72,847,795	USD 72,847,795	USD 72,847,795	USD 72,847,795	USD 72,847,795	USD 72,847,795	USD 72,847,795	USD 72,847,795	USD 72,847,795	USD 72,847,795	USD 72,847,795
Infrastructure Maintenance Cost	USD 0	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545
Rolling Stock Investment	USD 31,381,357	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0
Rail operational cost	USD 0	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648
Road operational cost (1st year)	USD 220,881,931														
Result	*USD 325,111,082*	*USD 187,140,987*	*USD 187,140,987*	*USD 187,140,987*	*USD 187,140,987*	*USD 187,140,987*	*USD 187,140,987*	*USD 187,140,987*	*USD 187,140,987*	*USD 187,140,987*	*USD 187,140,987*	*USD 187,140,987*	*USD 187,140,987*	*USD 187,140,987*	*USD 187,140,987*
NPV	**USD 1,214,256,609**														
Total volume transported in 15 years	15,000,000	ton													
$ current/tonne	81.0	USD/ton													

Gvnt investment interest rate	5.0%	USD 578,367,609	$578,367,609.00	USD 0											
Alternative B3.1	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Infrastructure investment	USD 55,721,259	USD 55,721,259	USD 55,721,259	USD 55,721,259	USD 55,721,259	USD 55,721,259	USD 55,721,259	USD 55,721,259	USD 55,721,259	USD 55,721,259	USD 55,721,259	USD 55,721,259	USD 55,721,259	USD 55,721,259	USD 55,721,259
Infrastructure Maintenance Cost	USD 0	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545
Rolling Stock Investment	USD 31,381,357	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0
Rail operational cost	USD 0	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648
Road operational cost (1st year)	USD 220,881,931														
Result	*USD 307,984,546*	*USD 170,014,451*	*USD 170,014,451*	*USD 170,014,451*	*USD 170,014,451*	*USD 170,014,451*	*USD 170,014,451*	*USD 170,014,451*	*USD 170,014,451*	*USD 170,014,451*	*USD 170,014,451*	*USD 170,014,451*	*USD 170,014,451*	*USD 170,014,451*	*USD 170,014,451*
NPV	**USD 1,114,111,413**														
Total volume transported in 15 years	15,000,000	ton													
$ current/tonne	74.3	USD/ton													

Gvnt investment interest rate	0.0%	USD 504,201,319	$504,201,319.26	USD 0											
Alternative B3.1	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**
Volume transported (tonnes)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Infrastructure investment	USD 33,613,421	USD 33,613,421	USD 33,613,421	USD 33,613,421	USD 33,613,421	USD 33,613,421	USD 33,613,421	USD 33,613,421	USD 33,613,421	USD 33,613,421	USD 33,613,421	USD 33,613,421	USD 33,613,421	USD 33,613,421	USD 33,613,421
Infrastructure Maintenance Cost	USD 0	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545	USD 14,381,545
Rolling Stock Investment	USD 31,381,357	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0	USD 0
Rail operational cost	USD 0	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648	USD 99,911,648
Road operational cost (1st year)	USD 220,881,931														
Result	*USD 285,876,709*	*USD 147,906,614*	*USD 147,906,614*	*USD 147,906,614*	*USD 147,906,614*	*USD 147,906,614*	*USD 147,906,614*	*USD 147,906,614*	*USD 147,906,614*	*USD 147,906,614*	*USD 147,906,614*	*USD 147,906,614*	*USD 147,906,614*	*USD 147,906,614*	*USD 147,906,614*
NPV	**USD 984,838,707**														
Total volume transported in 15 years	15,000,000	ton													
$ current/tonne	65.7	USD/ton													

Table A-5 Detailed Fiscal Analysis (Author)

Alternative B2.2	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Infrastructure investment	-USD 528,094,629	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	USD 143,718,724
Additional fiscal income per year	USD 0	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987
Savings in externalities	USD 0	USD 17,639,923	USD 17,639,923	USD 17,639,923	USD 17,639,923	USD 17,639,923	USD 17,639,923	USD 17,639,923	USD 17,639,923	USD 17,639,923	USD 17,639,923	USD 17,639,923	USD 17,639,923	USD 17,639,923	USD 17,639,923
Result	*-USD 528,094,629*	*USD 250,424,246*	*USD 250,424,246*	*USD 250,424,246*	*USD 250,424,246*	*USD 250,424,246*	*USD 250,424,246*	*USD 250,424,246*	*USD 250,424,246*	*USD 250,424,246*	*USD 250,424,246*	*USD 250,424,246*	*USD 250,424,246*	*USD 250,424,246*	*USD 404,802,635*
NPV	**USD 1,376,720,068**														
IRR	47%														

Tasa de descuento 8.75%

Alternative B2.2	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Infrastructure investment	-USD 528,094,629	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	-USD 10,659,664	USD 143,718,724
Additional fiscal income per year	USD 0	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987	USD 243,443,987
Result	*-USD 528,094,629*	*USD 232,784,323*	*USD 232,784,323*	*USD 232,784,323*	*USD 232,784,323*	*USD 232,784,323*	*USD 232,784,323*	*USD 232,784,323*	*USD 232,784,323*	*USD 232,784,323*	*USD 232,784,323*	*USD 232,784,323*	*USD 232,784,323*	*USD 232,784,323*	*USD 387,162,712*
NPV	**USD 1,248,627,715**														
IRR	44%														

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