Using Advanced Digital Technologies to Introduce Pioneering Economic and Financial Analytics in the Natural Gas Sector

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Abstract

During the past decade, natural gas markets have witnessed several critical upheavals: increasing market volatility, greater geopolitical risks and penetration of disruptive technologies. In this fast evolving environment, uncertainty expands without any frontier along many dimensions simultaneously. Against this background of tidal changes, the identification and assessment of incoming economic opportunities and risks has become decisive. This is particularly the case for the industry whose daily practice has seldom evolved since Shell developed corporate scenarios modeling. Investment opportunities and risks evaluation are usually performed on a limited set of economic and financial indicators, with sensitivities around a constrained number of scenarios, each of which is based on sensitivities around a restricted set of input hypotheses. These self-restrained, hence by-design partial views of assets, produce typically on participants to the evaluation process an almost gated-community feeling of safety in the results. In fact, these curtailed views actually maintain huge blind zones as to the upside and downside around the business cases under consideration. In the context of an increasingly complex, difficult and violent environment, these classic economic and financial analytics simply cannot keep up with the task.

In this paper, we present an innovative method to overcome the challenge by leveraging advanced digital technologies in terms of abstract syntax trees and data visualization. Our approach consists in the systemic assessment of an exhaustive continuum of physically possible outcomes to identify the underlying key risks and opportunities areas associated with natural gas production assets, hence building a risk-opportunity topology along several dimensions. We demonstrate that such risk-opportunity topologies enable their users to depart from a hope-for-the-best attitude towards the traditional low-medium-high scenarios and achieve a systemic understanding where the risk-opportunity continuum can be characterized into fragile, robust and anti-fragile areas.

The applications are very wide-ranging. In our paper, we present (1) the building and the use of multi-dimensional supply curves for natural gas traders, (2) the continuous economic assessment of natural gas production assets financial performance for both portfolio managers and investment committees, (3) the overall management of tax systems into an uninterrupted economic environment for natural gas producing countries’ Governments and (4) the supply of a breakthrough natural gas modeling system with state-of-the-art data for strategy analysts and market forecasters.

Beyond the specific case of natural gas, our techniques can be easily adapted to all sectors of the economy.

* The views expressed are those of the authors and do not necessarily reflect the views of ENGIE or We Are Ants.
Introduction

An abundant literature has been historically generated to propose and to describe techniques of strategic leadership and prospective approaches to support human organizations in managing the uncertainty and volatility of their environment. Among those approaches, the scenario planning technique has held a key role since it was developed by the Royal Dutch Shell to adapt the company to the 1970s sharp oil prices developments. Our goal is to pursue this reflection and to leverage advanced digital technologies to demonstrate a further approach with a wide range of applications in the natural gas sector. In that respect, we sum up, deepen and expand our preliminary efforts to provide natural gas traders with advanced simulation solution to overcome limitations to forecasting scenarios (Enderlin et al., 2017).

We begin with an overview on the limitations of the scenario planning approach as it has been used to perform the strategic leadership since the 1970s. We pursue by the introduction to the concept of post-strategic thinking as a concrete application of the essayist Taleb’s philosophical proposition to grasp uncertainty. In the final section, we present the execution of this new approach to the natural gas economics through the use of Abstract Syntax Trees (AST) as an advanced digital technology.

1. Limitations of the scenario planning approach to strategic leadership

Strategic leadership has historically played a significant role in any human organization, from the military area to the business sphere without forgetting Governments circles. Hughes and Beatty (2005) provide a clear and concise definition of this concept:

“Individuals and teams enact strategic leadership when they think, act, and influence in ways that promote the sustainable competitive advantage of the organization.”

As a direct result of this definition, the ability for a given organization to understand and to anticipate its own operating environment has become a prerequisite for any success. This opened the prospective studies field of research aiming at providing top managers with a clear vision of the future to support their decisions-making processes. The primary solution to manage or even reduce the uncertainty around the future was to establish a development plan based on a single forecast. The nature of this forecast obviously depended upon the type of organization: for example for the military, it typically revolved around what will be the concrete threats emerging in the medium to long-term? In the natural gas business or in any other commodity business, the emphasis is basically on issues such as what will be the future price of the product? etc. Unfortunately, the various and regular gaps between these forecasts and reality went so far as to question the single-based forecast exercise itself.

In the 1970s, Wack (1985) developed an alternative methodology to support the Shell Française (the former subsidiary of the Royal Dutch Shell in France) in dealing with economic uncertainty by moving from a single forecast to a a then innovative technique: the scenario planning technique. The new approach consisted in giving up the hope-for-the-best single forecast by accepting and integrating the uncertainty within the company strategic thinking. To achieve this, Wack initiated the elaboration of a set of explanatory, possible and differentiated future economic environments with the aim to simulate the company’s top managers thinking. For this process to work efficiently, the author set two conditions: on the one hand, the scenarios had to be based on intelligible analysis of reality and on the other hand, they had to make the top managers giving up their certitude to reorganize their mental models of reality. With regular updates, this process helped the company to remain flexible and attentive to weak signals to finally adjust well to sudden economic changes. This approach is said to have enhanced Shell’s management readiness to the eventuality of the 1973 oil crisis and the 1980s oil glut.
Since then, the scenario planning methodology has been adopted as a standard approach widely used by experts from private, Government and academic sectors for their investment decisions, planning and policy-making globally. For illustration, the International Energy Agency publishes annually several reference documents to provide its member countries with advice on energy security, economic development and environmental protection. Among these documents, the World Energy Outlook is based around 3 differentiated scenarios which are well known to all energy economists: one baseline scenario (New Policies Scenario) and two alternative scenarios (Current Policies Scenario and 450 Scenario). The same applies for the Energy Technology Perspectives which also presents 3 scenarios based on the long-term limitation of the global temperature increase (2DS, 4DS and 6DS). Johnson et al. (2014) present the elaboration of scenarios as a key tool to help managers in grasping the uncertainty and the complexity of rapid changes in business environments. They give details on one way to carry out scenario analysis through 5 basic steps: (1) defining the scenario scope, (2) identifying the key drivers for change, (3) developing scenario ‘stories’, (4) identifying impacts of alternative scenarios on organizations and (5) establishing early warning systems.

Even if the planning scenario technique has so far allowed to provide relevant analysis on the future economic environment, some limitations have emerged for some time now. Paltsev (2016) shows the difficulty of policy makers to understand and to assimilate the results of economic studies due to the glut of climate scenarios which suggests that ‘almost everything is possible’ in the context of the struggle against climate change.

![Figure 1 Global total primary energy use in the scenarios consistent with 2°C warming: Historic data and projections up to 2100. Data: IEA and AR5 Scenario Database, Analysis: Paltsev (2016)](image)

On the basis of these observations, Paltsev warns decision-makers against the strong belief in any given scenario as a precisely definite estimate of the future. Nevertheless, he recognized the value of building quantitative scenarios to support decision-makers in assessing the scale of any transformation.

It seems clear that the scenarios-based methodology developed by Wack in the 1970s has played a significant role in improving organizations’ ability to project into the future. Nevertheless, we believe that today’s World is structurally and quickly evolving towards a complex environment in which uncertainty expands without any frontier along many dimensions simultaneously. In this disruptive context, the classic economic and financial analytics based on the scenario planning methodology simply cannot keep up with the task.
2. Introduction to the post-strategic thinking

2.1 A VUCA natural gas World

Towards the end of the Cold War, the United States Armed Forces appropriated the VUCA acronym to describe the new contextual environment emerging from the collapse of the USSR. VUCA stands for Volatility, Uncertainty, Complexity and Ambiguity. In its 3rd edition of its Strategic Leadership Primer (2010), the Department of Command, Leadership, and Management of the United States Army War College (USAWC) provides the basic implications of its constituent terms, we think it is relevant to reproduce here in details. For each concept, we give an example of our own reading of some of these implications for different aspects and players in the natural gas sector.

- **Volatility**: “the rate of change of the environment. Volatility in the Information Age means even the most current data may not provide an adequate context for decision making. Beyond an ability to accurately assess the current environment, leaders must anticipate rapid change and do their best to predict what may happen within the time scope of a project, program, or operation. Volatility in the environment coupled with the extended timelines of modern acquisition programs creates a special challenge for strategic leaders and their advisors.”

  In the natural gas sector, the volatility of prices is extremely difficult to apprehend for market players, particularly when attempting to embed this reality into their market expectations. The development of liquid hubs in Europe over the last decade has created new opportunities for these players as well as new fundamental market features yet to be fully apprehended: is there any threshold for prices and volumes which would trigger short-term decisions by Algeria, Norway or the Netherlands to reduce their production? Simply raising such questions through updating players’ market views may already generate endogenous volatility on European natural gas prices.

- **Uncertainty**: “the inability to know everything about a situation and the difficulty of predicting the nature and effect of change (the nexus of uncertainty and volatility). Uncertainty often delays decision-making processes and increases the likelihood of vastly divergent opinions about the future. It drives the need for intelligent risk management and hedging strategies.”

  Managing uncertainty is the key success factor for any committee assessing investment opportunities in new natural gas production facilities. Indeed, a minimum price is required over a given period to ensure such investment profitability. The uncertainty arises from the inability to predict or at least to understand the main drivers which could make this price dive below the minimum breakeven price. For example, the shale gas revolution which started in the US in the noughties is now shifting the country profile from net importer to net exporter. This structural change resulted in the collapse of global natural gas prices over the 2014-2015 period. Consequential impacts in the aftermath of this crisis are severe: in the medium term, recent investments’ profitability is directly threatened as revenues from natural gas are not sufficient to cover the full costs of capital. This concern appears also in several regions around the world even in historical oil and gas producing countries such as e.g. Russia (Yamal LNG).

- **Complexity**: “the difficulty of understanding the interactions of multiple parts or factors and of predicting the primary and subsequent effects of changing one or more factors in a highly interdependent system or even system of systems. Complexity differs from uncertainty; though it may be possible to predict immediate outcomes of single interactions within a broader web, the non-linear branches and sequels multiply so quickly - and double back on previous connections - so as to
overwhelm most assessment processes. Complexity could be said to create uncertainty because of the sheer volume of possible interactions and outcomes.”

The emergence and the strengthening of the LNG (Liquefied Natural Gas) market over the last decades has structurally generated more complexity in the overall natural gas business. Whereas the natural gas sector was historically developed around three main separated consuming regions (the US, Europe and Japan), each of which presented its own fundamentals in terms of supply and demand, the LNG market has enabled to cross and to mix these fundamentals while allowing new regions to join the business such as Australia and countries from Latin America and Africa. For example, the 2011 Fukushima tsunami developed into a major nuclear meltdown, triggering immediate mass substitution of shutdown natural production with natural gas power production. As a consequence, Asian natural gas demand surged, raising import prices and expected forward prices sharply, thus leading the re-routing of LNG tankers from Europe to Asia. Elaborating a medium and long term view on any of these regional markets now requires to take into account the Global LNG as a whole, thus increasing the complexity of the exercise.

- **Ambiguity:** “describes a specific type of uncertainty that results from differences in interpretation when contextual clues are insufficient to clarify meaning. Ironically, “ambiguous” is an ambiguous term, whose definition changes subtly depending on the context of its usage. For our purposes here, it refers to the difficulty of interpreting meaning when context is blurred by factors such as cultural blindness, cognitive bias, or limited perspective. At the strategic level, leaders can often legitimately interpret events in more than one way and the likelihood of misinterpretation is high.”

While most of worldwide natural gas producers meet the economic laws of supply and demand, some producing countries introduce alternative perspectives in their behavior toward the market dynamics. This is for illustration the case of the Russian Federation which used its natural gas supply as a lever of political and geopolitical influence throughout the Russia/Ukraine gas disputes of 2006 and 2009. Due to the ambiguity of the Russian behavior, European natural gas markets analysts will increasingly have to extend their scope from 100% market based studies to investigations crossing both market and geopolitical aspects.

To conclude, we believe that VUCA corresponds to a relevant description of today’s environment and perspectives in the natural gas sector. This increasingly complex and violent context calls for innovation in the way the strategic leadership has been initially designed with the final aim to tackle these new challenges and eventually make value from disorder.

### 2.2 Risk-opportunities topologies: fragile/antifragile/robust

Taleb provides an extremely wide, complex and original framework for thinking the management of uncertainty in INCERTO, a philosophical and practical essay on uncertainty which gathers in a single publication his essays Antifragile (2012), The Bed of Procrustes (2010), The Black Swan (2007), Fooled by Randomness (2001) described by the author as:

"an investigation of opacity, luck, uncertainty, probability, human error, risk, and decision making when we don’t understand the world, expressed in the form of a personal essay with autobiographical sections, stories, parables, and philosophical, historical, and scientific discussions in nonoverlapping volumes that can be accessed in any order."

Among other sectors, Taleb notices that the deep-rooted nature of the economic and financial system has generated a fragile situation where the achievement of the global system relied on individual components such as banks that were too big to fail. After the collapse of the system in 2008 and the beginning of the Great
Recession, international institutions and Governments have spent energy and efforts to try to make this system more robust. However, Taleb opines that the increasing complexity, volatility and uncertainty of the current economic environment make these attempts insufficient to keep up with the task. In contrast, he advises to innovate in the way both risks and opportunities have to be managed to finally benefit from the increasing disorder. For this purpose, Taleb proposes to abandon the classical method of predicting and calculating future probabilities and to adopt the building of maps of exposure. With this in mind, Taleb builds a matrix of structural systems which give variable types of reactions to a stimulus coming from the external environment:

- **Robust**: robust (or resilient) systems are neither harmed nor helped by volatility and disorder. This implies that the map of exposure is quite flat and smooth along the input dimensions when represented as graph.
- **Fragile**: fragile systems are penalized to some degree by uncertainty, disorder and the unknown. This implies that the map of exposure is sloppy along the input dimensions when represented as graph. These regions typically yield bifurcation and non-linear structural changes in the given environment.
- **Antifragile**: antifragile areas are the converse of fragile areas considering that the system benefit to some degree from uncertainty, disorder and the unknown.

The underlying idea consists in analyzing antifragile/fragile/robust areas on the maps of exposure to make the economic agent more agile and flexible and finally to help him making informed and relevant decisions.

### 2.3 Implementing the post-strategic thinking

In light of Taleb’s philosophy, we propose to pursue the quest initiated by Wack in the 1970s. Wack expanded the scope of prospective and strategic studies by developing multiple but discreet scenarios. Our approach consists in building the exhaustive continuum of physical possible outcomes which can be envisaged in order to build risk/opportunity topologies as conceptualized by Taleb. In practical terms, this implies admitting our ignorance – and openness to surprise – in testing systematically without prejudice every combinatorial scenario by meaningfully incrementing from the minimum to the maximum of each assumption.

Thus, for any given system, the first step consists in identifying the key drivers which can significantly impact it. For example, in the case of the evolution of any country’s Gross Domestic Product (GDP), these key determinants would be basically the labor productivity, the demographic change or the level of innovation.

The next step is to build a simulation system which can estimate the target indicator in analytical terms as a function of all identified key drivers. Then, this simulation system is operated over a combination of continuums on all key drivers. At this level, it is important to test exhaustive continuums of assumptions especially by taking into account extreme values. This aims at extending the scope of analysis to the anticipation of the consequential impact of extreme and highly unlikely situations described by Taleb as Black Swans. For illustration, the GDP should be typically assessed by considering a level of innovation ranging from 0 to 100%. This step typically requires very high levels of computing power and storage capacity.

Finally, the results are aggregated in the form of risk/opportunity topologies as a continuous function of the continuums of key drivers. This allows the identification of the fragile/antifragile/robust areas as described above. Due to the highly complex and non-linear relationships between the various determinants, the thus generated topologies are often jagged and uneven surfaces. For the simplification of the demonstration, it is helpful to limit the graphical representation to 3 dimensions but additional layers of analytical treatments combined with additional data visualization tools easily allow to study a greater number of dimensions.
On this basis, the post-strategic thinking consists in departing from the belief in a single scenario to move towards a flexible and agile behavior where managers make the maximum profit of evolving circumstances by exploiting a clear and intelligible view on their exhaustive environment.

In the following part, we operate a specific digital technology (the Syntax Abstract Tree) to apply the post-strategic thinking to a specific area (the natural gas sector). However, there is little doubt that this philosophy can be applied to a wide range of sectors with various technologies. In particular, the recent and massive development of technologies such as the machine learning or the artificial intelligence may allow to find appropriated solutions in other circumstances.

3. Applying the post-strategy thinking to the natural gas sector

To illustrate the effective implementation of such a philosophy, we take the example of recent developments we achieved in the area of economic analysis in the natural gas sector. We first present our working database with the aim to decisively introduce and to put into perspective our technological breakthrough. Finally, we present some of our results to illustrate an actual implementation and how the post-strategy thinking can be put into practice.

3.1 The market database

As an important gamerplayer in the fields of oil and natural gas production, ENGIE maintains and updates a complete database of estimated business plans, each of whom provides economic, financial and technical informations on every competitors’ production assets (Norway, Algeria, etc.). By construction, a business plan is a model which describes the economic and financial projections associated with a project on the basis of some exogenous assumptions. In the specific case of hydrocarbon production projects, the expected oil and gas prices as well as the expected production volumes are typical assumptions.
Each one of these business plans has been implemented into a specific Microsoft Office Excel file as closest as possible to the actual operational, economic and financial realities to be managed. It provides with high degrees of freedom and flexibility to implement the business model which integrates complex elements such as the fiscal models. Indeed, most of production licenses between Governments and oil and gas producers are negotiated by specific fiscal agreements. In practice, this means that each Excel file design is different depending on the fiscal terms in force and which may call for a batch of specific fiscal mechanisms among the more than 700 mechanisms which have so far been identified: cross-taxation on the produced volumes of oil and gas, incremental taxation of profits, etc. For example, the information provided by the Norwegian Petroleum Directorate (NPD) were of special interest to create the database for the Norwegian market.

Thanks to several years of work, we now have an accurate database which provides an almost exhaustive view on several tens of thousands of production assets in the areas of concern for ENGIE and even wider. Up to now, these Excel files were mainly used to increment views on our competition with the aim to benchmark our own activities. Indeed, we have an accurate view on each business plan with tax systems implemented on an asset-by-asset basis but the flip side of the coin is that these business plans are extremely heavy and complex to manipulate: each Excel file contains an average number of more than 40,000 Excel cells which are linked together with at least 60,000 complex Excel formulas including functions such as for example vlookup, index, if, match, npv, etc.

3.2 The technological breakthrough

As described above, our wide collection of Excel business plans enabled us to develop an accurate view on almost all oil and gas producing assets in the world. A modern Excel file is in fact a compressed (zipped) folder containing several Extensible Markup Language (xml) files in which the data, the formulas and formatting are stored. It is possible to instantiate Excel in order to incrementally update the target variables for each file through the Windows API, in particular the price and volumes-strip and then update the formulas for our business plans. However, due to the enormous size of the collection and the breadth of the files themselves, performing any significant computing would have required at least several months to perform our post-strategy method.

In an effort to tackle this challenge, we decided to spare with Excel instantiation and streamline the files’contents to be suitable for lower level and much faster treatment. This required to convert the Excel files contents from an object oriented abstraction towards an executable procedure. We therefore developed PTOLEMY, a tool which converts any pre-existing Excel output into an Abstract Syntax Tree (AST). Jones describes ASTs as algorithms which capture the essential structure of a given input in a tree form while omitting unnecessary syntactic details. In concrete terms, PTOLEMY conceptually uses arcs and nodes to transform each Excel output cell into a wide-range graph of input cells and functional treatments. This model combines the advantages of both databases and algorithms:

- **Database**: each leaf of the AST represents an input Excel cell (value) from the business plan.

- **Algorithm**: intermediate nodes represent operators and elementary Excel functions (vlookup, index, etc.), and arcs will coordinate the functions calls (arguments order, nested formula relations, associativity and commutativity of operators, volatile functions, etc.).
PTOLEMY converts a pre-existing complex Excel file into complex multigraphs of AST

Whilst several commercial solutions already exist, we went shopping for an open-source equivalent and came across both Pycel and OpenPyXL as our starting points. Pycel is an algorithm developed by Gorissen (2011) as part of the design of Unmanned Aerial Vehicles (UAV or drones) workflow for the BAE Systems aerospace and defence company and offered the advantages of implementing great, simple and robust core technologies we needed. In particular, this includes Bachtal's algorithm to tokenize and Shunting-yard’s algorithm to parse the formulas into AST ready for mapping Excel cells into programming codes (see Edison, 2014).

Pycel had also been quite extensively developed to identify seed cells or in other words, cells which do not depend on any other cells for their evaluation. Thus, by managing the dependency of seed cells onwards, the network of interrelationships is completely mapped. In addition PyCel set of Excel formulas was rather limited and was considerably expended upon by our development team. Finally PyCel could not manage relative cells dependencies as ranged names and some relative or dual yield functions which we implemented too.

Figure 4 Screenshot of the graphic representation of one multigraph generated by the conversion of an Excel business plan composed of 43,000 data and 53,000 relationships.
On the other hand, Pycel method to read Excel worksheets was exclusively built on Excel instance automation, which is not adapted to large-scale and distributed batch processes. For this specific issue, OpenPyXL is a well-suited solution, reading and writing worksheets without Excel. Note that PTOLEMY converts any Excel file and therefore maintains the causy and confortable ergonomics of Excel whilst at the same time enabling machine treatment at a considerable speed.

Thanks to this advanced digital solution, PTOLEMY tests the reaction of the Excel files under incremental hypotheses on pre-identified variables in a fraction of time. In the case of our oil and gas business plans, assessing a continuum of gas prices will automatically generate the associated continuum of Net Present Values (NPV). In that way, we built a bridge between on one side, business analysts who benefit from the extensive ergonomics and flexibility of Excel to transfer their analysis and business modeling into xml files and on the other side, strategists who can now grasp an aggregated and compact knowledge from this highly disseminated intelligence.

3.3 Performing post-strategy approaches in the natural gas sector

3.3.1 Defining natural gas production costs

To give a wide overview of the range of new opportunities that may be explored by using the technological breakthrough described above, we base our demonstration on the work achieved by Kleinberg et al. (2016). In this reference paper, the authors emphasize general misunderstandings in the literature and in public debates concerning the definitions of production costs and in particular dollar per barrel breakeven points for hydrocarbon production projects. To overcome this situation, they clarify the purposes of several benchmarks and propose standardized definitions. We retain here 3 definitions.

![Figure 5 Components of various breakeven points as published by Kleinberg et al. (2016)](image-url)
Lifting Cost

Lifting cost is the marginal cost required to produce one additional barrel of oil or cubic meter of natural gas from an existing well in an existing field. This cost takes into account the cost of operating and maintaining equipment, fuels, labor cost but also taxes and royalties charged to production as well as the marginal cost required to transport the products to market. This economic regime is of special relevance to assess the minimum price level required by the producer in the short term to accept to keep producing, thus limiting its losses. Only if prices fall structurally below the lifting cost will the foreclosed capacity be mothballed or abandoned. By way of consequence, the lifting cost is the reference cost used by oil and natural gas traders to understand and anticipate market developments in the short term. From a temporal point of view, it has to be noticed that for a given business plan, the lifting cost assessed in $/MMBtu evolves from year to year given some input such as the expected production level and the tax regime for instance.

Full Cycle Breakeven

The full cycle breakeven is the price level which will makes the project’s NPV equal zero. Thus, it includes all the expenses of finding and delineating the resource as well as capital expenses, the cost of financing all activities and all lifting costs. It is the reference economic regime to assess project economics for investment committees which focus on planning investments and extending operations. As the NPV covers the full cycle of the project, the full cycle breakeven is identical from year to year given that the economic environment is stable.

Fiscal Breakeven

Whereas both lifting costs and full cycle breakeven are an estimation of production costs as perceived by the producer in a given economic environment, the fiscal breakeven is of different nature. It is the oil and/or gas price required to secure the Government’s income through the fiscal systems. In concrete terms, negotiating a fiscal treaty is equivalent to share the production margin between the production entity and the Government.

3.3.2 The economic duality of oil and gas productions

Several approaches are available to present the implementation of the post-strategic thinking. To ensure a comprehensive and instructing message, we base our demonstration on the economic duality between oil and gas production from various hydrocarbon production assets. For illustration purposes, we will ignore the production of other liquids than oil such as Natural Gas Liquids (NGLs) or condensates.

A hydrocarbon production asset can be economically represented as a generic project P associated with finding and development CAPital EXpenditures (CAPEX), production and fiscal OPerational EXpenditures (OPEX) and FINancial EXpenditures (FINEX). As for the revenues, they are the sum of the revenues provided by the production of oil and natural gas. As a matter of fact, natural gas and oil share the same geological nature of shorter or longer linear carbon chains. Depending on the characteristics of a given geological reservoir, in particular the burial depth of its charging source kitchen which influenced the temperature and pressure at which the original biological fats were pyrolysed, the ratio between the oil reserves and the natural gas reserves widely varies. The Gas/Oil Ratio (GOR, expressed in scf/bbl) is the reference metric used by the Society of Petroleum Engineers (SPE) to describe this characteristic.

<table>
<thead>
<tr>
<th>Category of reserve:</th>
<th>Black Oil</th>
<th>Retrograde Gas</th>
<th>Wet Gas</th>
<th>Dry Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOR ranges (scf/bbl):</td>
<td>&lt;1000</td>
<td>1000 – 15 000</td>
<td>15 000 – 100 000</td>
<td>&gt; 100 000</td>
</tr>
</tbody>
</table>

Figure 6 Reference ranges of GOR categories
What is true for hydrocarbon reserves also holds for production capacities: depending on the reservoir characteristics, the availability of transmission infrastructures and the availability of selling the production (buyers, hubs, etc.), the asset P will be designed to maximize the associated profits from the sale of both oil and gas volumes. The underlying duality of oil and gas productions has a major impact on the project economics as one cannot dissociate between operating costs with the oil or the natural gas production: the project P is composed, for example, of one offshore platform, one drilling well, one team of operators, etc.

As a result, a decrease in the oil price may be directly compensated by an increase in the gas price considering constant volumes of production. Conversely, a decrease in the production of natural gas through gas-cap reinjection to maintain pressure and hike oil recovery-rates is typically a financially sound trade-off. The short term and medium term economic balance of the production project P thus rests on the combination of both products.

In our vision of the natural gas market, the natural gas production costs are relative to the oil price: the higher the oil price, the lower the minimum gas price required to balance the shared production costs and vice versa. These dynamics have increased in importance over the last decade due to the development of gas hubs in parallel of the progressive disappearance of the oil-price indexation for natural gas supply contracts leading to an oil and gas prices disentanglement. Furthermore, the wide ranges of both oil and natural gas market prices historically observed worldwide make crucial the dual study of the combinatorial production costs of one commodity against the other.

In the following parts, we propose a description of our way to implement the post-strategic thinking in the natural gas sector by using PTOLEMY. The ingenuity of the approach results from the possibility offered by PTOLEMY to grasp an extremely compact knowledge from the deeply disseminated intelligence contained in a huge number of Excel files. Thus, we use PTOLEMY to test the aggregated reaction of the business plans to different various oil and gas prices considering different economic regimes: lifting costs, full cycle breakeven and fiscal breakeven.

3.3.3 Building and exploring multi-dimensional supply curves for natural gas traders

Physical traders operate on the short term allocation market by dispatching gas volumes produced by existing or forthcoming assets. Among other regions, the integration of European natural gas markets has significantly progressed over the last decade. For example, an information issued from Norway announcing a fortuitous shut-down of a producing asset may instantly induce a strong increase in the price volatility over several European gas hubs (NBP, TTF, Zeebrugge, etc.). For this reason, the understanding of the natural gas production costs structure considering the lifting cost regime of the different European suppliers is of great interest for this category of market players.

Our approach consists in operating PTOLEMY on the exhaustive business plans of a given natural gas producing country to generate an aggregated risk and opportunity topology. First, PTOLEMY injects an assumption on the oil price for the year 2017 in each business plan. Then, the tool operates the 2017 gas price on an asset-by-asset basis to make the lifting cost regime of each asset equal zero. These operations result in a 2-dimension supply curve where the negative values along the y-axis represent the contribution of oil sales whereas the positive values represent the contribution of gas sales required to balance the lifting cost regime.
Figure 7 Elaborating the natural gas supply curve in lifting cost regime under a 40$/bbl oil price assumption for the assets producing natural gas in Algeria in 2017.

Remark: insofar as the absolute values of the production costs are not necessary essential to this illustration and the following ones, they have been removed.

There are several reasons why the cost structure widely varies from an asset to another. The assets are particularly sensitive to the GOR which may bring structural and differentiated impacts on the oil contribution. It has to be noticed that for some fields located at the left side of the supply curve, the oil contribution is sufficient to cover the complete lifting cost regime, and even to generate a margin in some cases. The fiscal systems are the other key driver of these variations as they vary from one asset to another in terms of both mechanisms and parameters.

Then, PTOLEMY incrementally operates this process considering a continuum of assumed oil price from 0 to 80 $/bbl with an incremental step of 1 $/bbl. The operations are repeated for each asset of the producing country which is being studied. The strengths of PTOLEMY hold on its ability to solve the evolving problems regardless of the complexity and the diversity of the fiscal mechanisms. As an output, a 3-dimension topology can be generated for the year 2017 on which can be characterized different risk/opportunity areas.

Figure 8 Risk/opportunity topology of the natural gas lifting production costs of Algeria in 2017 as a function of the oil price and the natural gas production capacity.
In that way, whatever are the short term market developments in terms of oil and gas prices evolutions, the natural gas traders instantly have an accurate view on the consequential results for the producing country: does the market get closer to a fragile area? Does the market still evolve in a robust area? etc. In that way, we move from the traditional scalar approach (“the average natural gas production cost of Algeria is xx $/MMBtu”) to an operational aspect of the post-strategic thinking (“considering an oil price of yy $/bbl and a natural gas price of zz $/MMbtu, Algeria is located in a robust zone”).

3.3.4 Elaborating and using exhaustive sensitivities on economic environments to support investment committees and to optimize assets portfolios

The reasoning is similar for investment committees and portfolio managers who are focused on the financial aspects of production assets. In this case, PTOLEMY injects exogenous and continuous assumptions on both oil and gas prices in each business plan for a given portfolio and for a given year. For each couple of commodity prices, PTOLEMY extracts the complete value chain generated by the portfolio under these economic conditions: revenues from oil and gas sales, production costs, taxes, etc. For the illustration, we focus on the Net Operating Profit After Taxes (NOPAT) defined by Brealey et al. (2013) as a reference indicator for corporate finance. By definition, this metric aims at covering the OPEX, the taxes, the amortization of past investments as well as the investment of the year under study as a corollary to the full cycle breakeven.

Then, the post-strategic thinking consists in building risk/opportunities topologies to identify the associated key areas. This approach opens up a wide range of prospects. The users can thus identify the combinatorial impact of oil and gas prices on the profitability of their assets: how close is the non-linear border from which the portfolio generates negative cash? Which direction among oil or gas axes is the most vulnerable? If the portfolio is too exposed to one commodity, how can I compensate with merger/acquisition actions to make the topology of my portfolio flat and thus balancing the risks between both commodities? Etc.

Figure 9 Risk/opportunities topology associated with a virtual portfolio which would be composed of all producing assets in Azerbaijan
3.3.5 Managing tax systems into an uninterrupted economic environment for natural gas producing countries’ Governments

The same modus operandi can produce risk/opportunity topologies to assess the revenue generated by the hydrocarbon production of producing countries within the framework of the fiscal breakeven calculation as described above. The technique is the same than the financial study of portfolios: PTOLEMY tests combined continuums of gas and oil prices on the exhaustive representation of producing assets’ business plans for a given country and for a given year. As a result, under these various economic conditions, PTOLEMY extracts the sum of all taxes generated from each fiscal mechanism such as royalties, taxes on the production, taxes on extraction, etc. As an output, we get a complete risk/opportunity topology of the country’s income generated by the oil and gas production.

In the case of Azerbaijan, we were able to make a distinction between the fiscal terms associated with the oil production and those associated with the gas production which improves the accuracy of our analysis to the differentiated exposure to both commodities.

Figure 10 Risk/opportunity topologies associated with the revenues of Azerbaijan with a differentiated view on taxes on natural gas (top), taxes on oil (middle) and the combination of both (down).
Levi (2015) recently criticized the massive use of breakeven figures by Governments, international organizations and strategists. The major cause of this reproach was the lack of details on both the methodology and data which led up areas of shadow regarding the 25%-correction in some estimates along a few months. PTOLEMY relies on a clear combination of both transparent technological and theoretical aspects to fulfill this task.

On the top of that, the topology built by PTOLEMY offers a wider view on the risks and opportunities for Governments of these producing countries: what is my differential exposure to oil and gas markets? How do I lead taxation reforms if I want to redirect my priority from producing oil to producing gas to fight against climate change? Etc.

3.3.6 Supplying natural gas modeling systems with models of realistic and evolving ranges of breakeven figures for strategy analysts and market forecasters

While pointing out the misunderstanding of the genuine of variable breakeven points, Kleinberg et al. finally recommend strategy analyst and market forecasters to improve their forecasts by incorporating realistic ranges of breakeven points and models of how they evolve under various conditions. In parallel, recent developments have been achieved by Enderlin et al. (2016 and 2017) to build a natural gas model which drops the standard pure static optimization approach in favor of a dynamic simulation architecture. This model aims at simulating and analyzing endogenous market disequilibria as a result of irreversible investment decisions made by independent market players on the basis of micro-economic foundations. Among other characteristics, this model makes a clear distinction between different markets environments in which the breakeven points evolve. To achieve this, the model simulates the impact of decisions made by investment committees to cover the full cycle breakeven of forthcoming investments on gas traders who focus on the short term allocation market which meets the law of the lifting cost regime of existing assets.

In its operational version, this market model is combined with PTOLEMY on the extended database of business plans on oil and gas activities described above. This integration allows assessing in real time the impact of incremental results provided by the market model (flow allocation, endogenous prices forecasts) on the business plans as realistically as possible. At this point, the high computing power and the possibility to assess business plans in various economic environments and economic regimes are key drivers for the efficiency of this new market model.

Conclusion

In this paper, we highlighted the limitations of the scenario planning approach to strategic leadership in an economic environment which structurally and globally becomes more and more complex. This especially stands for the natural gas sector which is evolving along the 4 dimensions of the VUCA notions: Volatility, Uncertainty, Complexity and Ambiguity. In the face of such challenges, we introduced the concept of post-strategy thinking which consists in the systemic assessment of an exhaustive continuum of physically possible outcomes to identify the underlying key risks and opportunities areas, hence enabling the elaboration of multidimensional risk-opportunity topologies. In the light of the exhaustive knowledge on their environment, managers and decisions makers can identify fragile/antifragile/robust areas and finally make profit of evolving circumstances.
In terms of application, we leveraged complex digital technologies in the form of Abstract Syntax Trees to offer a pragmatic application of the post-strategic thinking to a large panel of players in the natural gas sector. The tool developed for these analyses can be easily adapted to a wide range of business segments such as renewable energies, banking, insurance, etc. and thus enabling the elaboration of aggregated and transversal multi-dimensional risk/opportunity topologies. We leave the final words to a well-known expert of strategic leadership:

“I have conceived of many plans, but I was never free to execute one of them. For all that I held the rudder, and with a strong hand, the waves were always a good deal stronger. I was never in truth my own master; I was always governed by circumstances.”

Napoléon Bonaparte

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