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**STUDY GROUP 1.2**

**ASSESSMENT OF GLOBAL RESERVES AND RESOURCES OF NATURAL GAS**

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**Table of Contents**

[2 ASSESSMENT OF GLOBAL RESERVES AND RESOURCES 2.3](#_Toc364057548)

[Executive Summary 2.3](#_Toc364057549)

[2.1 Introduction 2.4](#_Toc364057550)

[2.2 Global conventional gas potential 2.4](#_Toc364057551)

[2.3 Global unconventional gas potential 2.4](#_Toc364057552)

[2.4 Gas flaring assessment 2.4](#_Toc364057553)

[2.5 E&P trends 2.4](#_Toc364057554)

[2.5.1 Gas pricing and exploratory risk 2.4](#_Toc364057555)

[2.5.2 Independent producers 2.7](#_Toc364057556)

[2.5.3 Gas discovery trends 2.8](#_Toc364057557)

[2.6 New exploratory frontiers 2.8](#_Toc364057558)

[References 2.23](#_Toc364057559)

[Appendices 2.24](#_Toc364057560)

[A List of Tables 2.24](#_Toc364057561)

[B List of Figures 2.25](#_Toc364057562)

[C Glossary and Acronyms 2.26](#_Toc364057563)

# ASSESSMENT OF GLOBAL RESERVES AND RESOURCES

## Executive Summary

Please write down a few paragraphs describing the job performed and its main conclusions.

## Introduction

Please write down a brief and attractive introduction that will encourage the reader to proceed.

## Global conventional gas potential

## Global unconventional gas potential

## Gas flaring assessment

## E&P trends

### Gas pricing and exploratory risk

In spite of growing reasoning in the open literature concerning the possibility of higher gas prices in the USA, so far the linkage with oil prices continues to remain shattered, inspiring the development of hub trading in other parts of the world, in opposition to the traditional long term contracts indexed in oil (Figure 2.1).

Unfortunately, there is now a general belief in the sense that hub pricing implies in cheaper gas, which is just not true, as pointed out by many important authors (see, for example, Bowden 2012 and Komlev 2013).

Figure 2.1 Gas and oil prices in the USA and Europe.

It is a matter of fact, however, that gas on gas competition (GOG) is gradually replacing oil price escalation (OPE) as a pricing mechanism, as indicated in Table 2.1 (Bowden, 2012).

Table 2.1 In Europe hub pricing (GOG) is replacing contracts indexed in oil (OPE).



According to Stern (2013), about half of the gas sold in Europe is at hub prices now, and this will continue to grow. For Komlev (2013), however, hub indexed gas would account for only 30% of the final consumption (Figure 2.2).



Figure 2.2 Hub vs. oil indexation in Europe (Komlev, 2013).

Whatever the real percentage actually is, the fact is that hub pricing transfers downstream risks to gas producers. Combined with the current low prices, this represents a major challenge for them, especially when unconventional gas is involved, as the costs are much higher.

In addition to that, important IOCs and NOCs have substantially increased the relative participation of gas business in their portfolios over the last years, which just adds to the current imbroglio (Figure 2.3).



Figure 2.3 Oil and gas production (in thousands of barrels per day) from some of the largest oil companies (Monteiro, 2013).

Hub pricing is increasing in importance, causing the market risks to be transferred from the downstream to the upstream segment of the gas chain. Wellhead prices will have to reflect that; producers will be less encouraged to perform investment in places where the risk is high.

### Independent producers

A large number of independent producers have consistently appeared as the most admired exploring companies in a traditional survey that is regularly published by Wood Mackenzie (Figure 2.4).

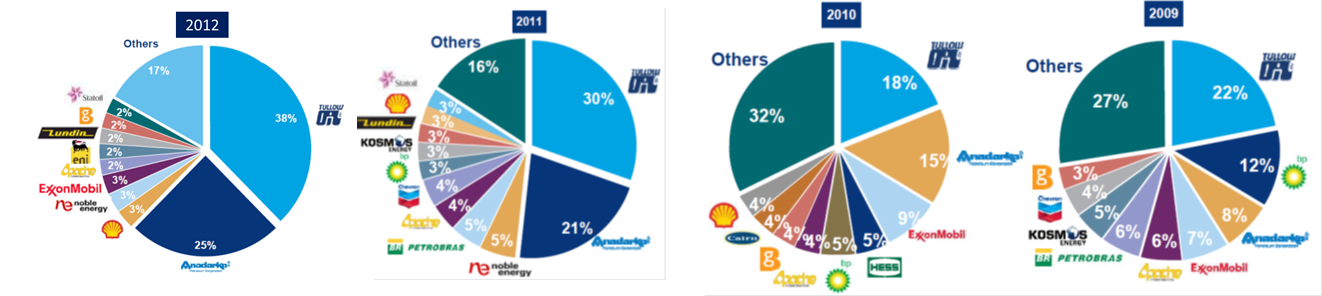


Figure 2.4. Most admired explorers in the world (Wood Mackenzie, 2012).

Tullow has been appointed by far the number one for its technical strength, vision and persistence, while Anadarko is often mentioned for its ability to solidly move into completely new areas, always sustained by a sound geological work.

In the meantime, important IOCs and NOCs such as BP, Petrobras, Exxon Mobil, Shell and Statoil seem to be losing ground in the exploratory shop window.

Where are the independents focusing their exploratory efforts and operations? How much oil and gas are they into?

### Gas discovery trends

In the 2009-2012 report this subtopic was included here, under “E&P trends”, but it seems to fit better in the next topic, “discovery trends and new exploratory frontiers”. Perhaps we should rename the current topic to “Upstream business trends”.

In the previous triennium, WOC 1 pointed out North Australia as the “hottest” conventional gas play. Carnarvon, Browse and Bonaparte basins contributed with 17% of the global gas volumes discovered between 2000 and 2009.

During the same time interval, gas discoveries in excess of 4 billion boe (technical) were discovered in Kazakhstan (Precaspian Basin), Egypt (Nile Delta), Brazil (Santos Basin) and China (Sichuan Basin).

More recently, however, huge gas finds have been pinned in the East African deep waters. As a matter of fact, most of the new finds are located in deep waters, and the percentage of gas in new discoveries has increased significantly as well.

Mozambique was certainly one of the stars, with 50 TCF added within a couple of years, and so were Angola and Tanzania.

## Discovery trends and new exploratory frontiers

### New exploratory frontiers

The text below is taken from the previous report for 2009-2012, for the moment the idea is to freshen it up with new exploratory developments.

The survey indicated the most attractive resource potentials to be dependent on the geographic region of the respondents (Figure 2.5).



Figure 2.5 Most attractive resource potentials indicated in a WoodMackenzie’s survey (2013).

As can be seen, the focus of exploration appears to be shifting towards riskier basins and more challenging settings, lifting the economic thresholds.

#### New or Frontier Exploration

A Frontier Basin or Play is a basin or a play where the exploration activities have not been carried out sufficiently, and where it is considered that there is a significant part of hydrocarbon that could be categorized as undiscovered volume.

As a result, New or Frontier exploration is an activity on basins or plays that, in the past, were either unexplored, underexplored or explored with techniques that were not adequate (either from low data acquisition or poor production tests). It resulted in poor knowledge of the concept.

Frontier exploration is linked with geological risk and uncertainty, that may also be difficult to be determined accurately. This uncertainty reflects in low Probabilities of successes, that impair the economic return evaluations. The economic analysis on Frontier areas is often not easy as it relies heavily on first successes to unlock the areas, which are difficult unpredictable.

In that category we can put:

- Areas that are remote or difficult to reach

- Areas that are difficult to operate due to the environmental conditions

- Areas where there is a lack of export infrastructure

- Areas/plays for which evaluation techniques allowed to gather new valuable data.

- Areas/plays for which application of new production techniques allowed to produce hydrocarbon for previously non producible considered areas.

- Areas that were not considered as of prime interest, either because they were in the shadow of easier to produce plays or basins or because they were not considered as rich

- Areas that are locked by regulatory authorities

For the large majority of the cases, frontier or new exploration is generally linked and sustained by innovative technology, as there are areas for which the potential is known to exist but for which industry is waiting for the sufficient breakthrough in technology. Breakthrough in technologies specially developed for identified exploration zones are likely to unlock potential in other basins that have similarities. For example, the progress in imaging techniques of the pre-salt, object of extensive developments for Gulf of Mexico or Offshore Brazil, played a role in underlying potential in Eastern Mediterranean region. Similarly, progression of deep water drilling, sustained by the investment made for Offshore Brazil are most likely responsible for the offshore exploration progress recently made in East Africa.

Of course, although gas and oil exploration is applying high level technologies, the progression in exploration, and the opening of new areas are mainly attributable to the analysis and experience of the geoscientist community.

Finally, as exploring for new plays is a challenging and risky business, we can remark that the opening of new plays is often led by entrepreneurial independent companies having the guts to chase new concept. This approach might be a company maker in case of success, but can also lead to disappointment.

In the recent past, we can mention Apache Company for gas exploration in Egypt, but also Tullow for Oil exploration in Ghana. At present Anadarko in Mozambique as well as Noble in East Mediterranean area, are proving that it is possible to open new plays.

Nevertheless, the best promoters for new exploration are the regulatory authorities and states. The support of governments is key for risky exploration, by setting incentive fiscal regimes that promote enough reward in case of success of new, therefore risky, exploration.

According to Oil and Gas in Africa, 2009 study, higher exploration and production costs and risks associated with limited reserves or deepwater offshore exploration often require flexible fiscal terms for exploration companies. Coherent principles, structures, and, above all, due diligence in enforcement, are key factors in increasing benefits and sustainability for all countries, and in particular attract investment for new exploration. In addition, in order to attract investment to the oil and gas sector, laws, regulations, and policies governing the industry should be clear, complete, transparent, accessible, flexible, and practical. Also, a consultative process should be institutionalized to ensure periodic dialog with operators to ensure that regulations are technically feasible and cost-effective.

All these elements have a major impact on the promotion of new zones, and may attract or divert investment on exploration, especially as non discovered resources in gas are still considered as high.

As a matter of fact, there is a general consensus that there are still numerous areas to explore for gas as, in the past, gas was underexplored compared to oil. The recent success in new areas is confirming this consensus.

The USGS assessment of undiscovered conventional gas considers that around 34% of the endowment is still to be discovered. The quantities still to be discovered are therefore quite significant, representing a mean value of around 5200tcf (530 tcf for the US and 4670 tcf for the rest of the world).

We identified some areas that are most likely to be the areas for gas exploration for the next ten years.

These areas are amongst many other:

- The Artic Circle, concentrating most of the undiscovered potential

- The underexplored areas of the Middle East for gas, (Western Irak Basin, Saudi Arabia, Iranian Zagros)

- The Levantive basin, recently emerging as one unexpected province

- Australian Offshore North West Shelf

- Eastern Africa

Atlantic subsalt areas (especially Santos and Campos Basins) although clearly focus of exploration, are not covered in this chapter as they are already widely addressed in other parts of the report. As mentioned previously, exploration of unconventional gas is also not addressed in this chapter, although it will be the focus of a lot of attention in the next years, specially in China, Australia, South America and Northern Africa.

The present chapter has been using amongst other sources the International Oil letters from IHS Company and Upstream services, and Upstream Insight letter from Wood Mackenzie Company.

#### The Arctic circle areas

The Area North of Arctic Circle is huge. This area covers an extent of more than 21 Million Km²: 6 % of the Earth’s surface) and the Arctic ocean has the most extensive continental shelves of any ocean basin (Shelf area under 500m is over 7 millions Km2), and most of it is in water depths of less than 50 m (mainly in Russian part).

The area belongs to 5 countries, and 13 main basins have been outlined:

- Norway: the Norwegian Sea and the West Barents basins

- Russia: the East Barents, Kara Sea, Laptev Sea, East Siberian Sea and South Chukchi Sea basins

- USA: the North Chukchi Sea and the North Slope basins

- Canada: the Mackenzie, Beaufort and Sverdrup basins

- Denmark: the Northwest and Northeast Greenland basins

The Arctic basins range from the proven offshore basins (West & East Barents and Sverdrup) to the offshore extensions of the proven onshore plays (Alaskan North Slope, Beaufort, Mackenzie & Yamal Peninsula) to the entirely unexplored seas of offshore Eastern Siberia, and Eastern & Western Greenland.

The Arctic area is already an important global gas producing region, with the presence of the biggest clastics gas fields in the world of the Western Siberian area. The area has already been explored to some extent, in Canada, Russia, US (Alaska) and recently in the Norvegian sector of the Barents sea. USGS study report over 400 Oil and Gas fields discovered north of the Arctic circle already, containing about 10% of the conventional Oil and Gas resources (~240 bboe). In addition to the already discovered volumes, USGS considers that it contains 22% of the yet-to-find potential (USGS study, 2008).

These vast undiscovered volumes make it one of the few remaining frontier area to explore for natural gas. However, depending on the basins, first production may be expected in the near future (or already happening, e.g. Russian Yamal sector, Norvegian Barents Sea or Alaska) or deferred until 2030+.

The status of the exploration in these areas depends on the potential and on the difficulties of the operating under harsh conditions, and also on the national incentives to explore for new discoveries.

The situation of the different countries holding acreage is different:

#### Norway

Norway is expected to counterbalance the fall of production happening after 2011, and set a pro-exploration hydrocarbon law. The exploration of the Norwegian sector is already underway, following the development of Snohvit.

Presently about 60 % of the offshore area is opened for exploration, and about 25 % of the opened area is currently licensed. Exploration efforts in Norwegian waters currently focus on new targets in areas such as the Finnmark Platform, the Nordkapp Basin, the Western Margin, and the area up to the Spitsbergen.

Some areas, like the Lofoten area, in the northern part of the Norwegian Sea are believed to be prospective, but being in an environmentally sensitive area, it has not yet been opened for exploration.

Norway recently launched an Integrated Management Plan (IMP) for the Norwegian Sea. In this plan, Norway’s authorities have introduced a series of recommendations to allow the hydrocarbon industry to grow without a long-term environmental impact on the most ecologically sensitive areas of the Norwegian Continental Shelf. In addition, Norway stated that the Government will present a white paper on the Norwegian High North and Arctic policy for mid 2011, focusing on ensuring sustainable management and development of natural resources and on international cooperation to meet common challenges in the Arctic.

Recent discoveries, like the recent announcements of discoveries from Total north of Melkoya, could be an anchor for further exploration in this under explored area, as confirming the positives indicators of the potential of the Norwegian Barents sea, and providing good expectations of the development of export infrastructures in the area.

#### Russia

Within its boundary, Russia already has existing discovered reserves in the offshore Arctic of 3.4 billion barrels of oil and 254 TCF of gas. These existing reserves are situated in 3 main areas: The South Barents Sea, the Pechora Sea, and the Yamal-Nenets & Kara Sea area.

Although the exploration potential of Russia is clearly huge, Russia is currently focusing on the development of already discovered fields, either in the Yamal peninsula area or in the Barents sea.

The development of some major projects is still to concretize due to the operating difficulties of the environment. It is currently expected that these areas may be developed from now (Barents sea) to 2020’s.

Schtokman alone has gas reserves in the order of 100/130 TCF of gas, and official timings are for piped gas production to begin in 2013, followed by LNG in 2014. however, due to natural gas oversupply and the economic crisis, the shareholders decided on 5 February 2010 to postpone the project another 3 years; the pipeline gas production might start in 2016 and LNG production in 2017. The final investment decision will be made in early 2012. In addition, Gazprom cites the Yamal Peninsula’s 26 fields as holding 550 Tcf of ABC1 and C2 gas reserves and a further 770 TCf of resources (categories C3 and D).

Furthermore, South Kara Sea (Offshore Yamal) is largely under explored, with already mapped but undrilled structure around the two giant gas discoveries of Leningradskoye and Rusanovskoye (considered at potentially over 280 TCF each ).

The development of these mega projects will act as an anchor to develop the resources in the nearby areas. Additional resources are already identified in undrilled “smaller” structures around these projects.

Apart from these high grade exploration areas, there are other basins, that also have a large interest to explore, but that are likely to be developed in the 2030’s rather than before.

Laptev sea, East Siberian sea and Chuchi sea basins are located in poorly known areas, with no known offshore wells, only shallow wells onshore. The seismic is very limited or non existent. The exploration of these basins, further away from export routes and with harsh ice and climatic conditions, will require more time.

Exploration of the Russian Arctic sector will be a major focus of the industry in the next 30 years. This is clearly indicated by strategic alliances like the Rosneft/ExxonMobil agreement to collaborate on Russian Arctic area. The expansion of this exploration depends mainly on the rate of development of the major projects in the area. Development of existing discoveries is clearly an advantage, as they will provide a steady learning curve for the operators and will give them time to develop innovative strategies of exploration and to build specific technical solutions in this highly challenging and harsh environment.

The exploration might also be favored by the political decision to open this difficult acreage to non-russian companies, which is currently not the case, being limited to “strategic partnership”. Lifting uncertainty in licensing plans and timing is crucial to promote the development of these areas.

#### USA and Canada

So far in the USA, no export route exists for gas (35 TCF discovered, essentially in Prudhoe Bay) due to strong environmental constraints. There are however export routes for oil, set in place for major Alaskan projects (Prudhoe Bay, Burger…). Despite this lack of export route, the frontier Alaskan Chukchi sea attracted high interests from majors, with the Chukchi Sea Sale 193 (2008), with 667 bids on 488 licences (US$2.70 billion).

The US offshore arctic area is rather poorly explored (only 5 wells have been drilled in the beginning of the 1990’s, including the Burger discovery).

For Canada, the exploration is not new, as there was an active policy of developing the national resources in the 1970’s and 1980’s, peaking at over 70 wells per year in these periods and resulting in 48 significant oil and gas discoveries in the Beaufort-Mackenzie Basin and 20 in the Sverdup. The exploration has revived since the beginning of the XXIth century, with great level of interest in the offshore Beaufort Sea, where there is already a discovery (Gas and oil discovery of Amauligak). The 2008 Beaufort sea license attribution was recently a success.

For gas exploration, main areas are Mackenzie Delta area and in the Arctic islands (Sverdrup), which already proved successful in the past ‘Taglu (1971): 2.7 TCF, Parsons Lake (1972): 2.1 TCF and Niglintgak (1972): 0.8 TCF).

The main restraint for the expansion of the exploration is the lack of a gas export route. The Mackenzie Valley Gas Pipeline proposed in 2008 did not further progress. It has been delayed since 2007 by concerns over how the pipeline would be run and regulated. Canadian government is expected to take a share of the risks in order to debottleneck this area.

#### Greenland (Denmark)

In Greenland, there is no real discovery so far, but exploration activities are moving forward with the opening of license areas.

The opening of exploration in Greenland, provoked by the 2010 Northwest License calls that should be followed by the Northeast License calls in 2012, caused high excitement. One of the main reasons is the high expectations for this area, (estimated undiscovered volumes of 51 tcf for the West Greenland, and of 86 tcf for the East Greenland, according to USGS), linked to the perception that this area was nearly non-explored (limited seismic and 5 wells drilled in the 1970’s and one in 2000).

Cairn company is presently drilling ahead the first exploration wells following this call. Its first two wells in Baffin Bay encountered gas in thin sands and oil in volcanics, proving that there is a Petroleum system working, which was considered as one of the main risks in the area.

However, the discovery was later announced as non commercial. Up to now, the following wells proved disappointing. The main uncertainty at the moment is to identify a proper reservoir. Due to the extent of the basin, the initial disappointing results should not be considered as definitive killers, and further exploration should be required in order to revise expectations.

At the moment, high expectations are put on the East Greenland area, which will be opened after 2012. It is considered that this area is closely related from a geological point of view to the Norwegian sea & Barents sea basins. This is considered to be a clear focus on the Arctic exploration for the next 15 years.

#### Levantine Basin

The Levantine Basin is situated in the eastern Mediterranean area. Its surface is approximately 83,000 km2, between the Tartus fault to the North, Cyprus and Eratosthe¬nes Seamount to the West and the Nile Delta system to the South West.

Levantine basin as a prominent target emerged only in late 2000, concretized with the Tamar discovery. Previously, this basin had not been really explored, as imaging limitations only allowed to assess the shallower horizons. The only discoveries were consisting in biogenic gas in shallow Pliocene channel sand plays off Gaza and Southern Israel.

The new assessment of the basin following recent seismic indicated strong structuration and potential for hydrocarbon traps at deeper levels. The main shift on exploration that revealed the strong potential of the area was linked to the decision to drill through the Messinian salt for potentially HP/HT Early Miocene/Oligocene deep basin floor turbidites targets, suggested by the good exploration results in Nile Delta area.

Tamar discovery, announced as over 9 tcf, is the second biggest gas discovery in 2009. It was followed by Dalit smaller discovery (1.2 tcf) and overall Leviathan, estimated as 17 tcf, in 2010, that is considered to be one of the largest discovery of the last 10 years.

These two large successes completely changed the perception of the prospectivity of the area, both from local authorities, IOC’s and experts. The undiscovered potential jumped from being unassessed as too small to over 120 tcf in USGS evaluations. It was followed by preparation of licensing rounds in Syria, Lebanon and Cyprus.

Success of exploration in the area will largely be dependent on the Political situation in the area, either internal or between the different countries. There are issues relating to the definition of the maritime borders, either between Lebanon and Israel, but also between Cyprus and Turkey. In addition, there are historical tensions between Israel and its neighbors that may compromise involvement of majors companies in its waters.

In addition to these political tensions, the development costs attached to these projects adds another challenge. The Tamar and Leviathan discoveries, despite their size, are quite costly to develop. The water depth is ranging from 1000m to over 1500m and requires deepwater HP/HT drilling rigs for the targets depths around 5000 m subsea. Development of a production and export infrastructure in this new area will also be required to explore for potential targets of lesser importance than those of Tamar and Leviathan. The tax environment which has been recently raised may add another risk on exploration, and delay the investments.

However, it is largely considered that the Levantine basin will be one of the new exploration focuses in the next years. The success of exploration in this Eastern Mediterranean basin is also opening up new frontier exploration targets in other areas of Mediterranean sea, where similar sub salt play can be explored.

#### Middle East areas

The Middle East area is still considered as being the second most important region for gas reserves (either already discovered or still to explore) after former soviet Union.

According to the USGS evaluations, most of the gas undiscovered resources are situated in the deeper Paleozoic levels, which in total form account for more than 800tcf of undiscovered resources in this region.

Obviously, the 1990’s and the beginning of the XXIth century proved extremely successful for the gas exploration in Middle East, and in particular in Arabian peninsula and Iran. This period coincided with the extension of exploration, appreciation and production of the Permo-Triassic carbonates levels (Khuff and equivalent).

This play, believed to be sourced by the prolific Silurian hot shales, is still proving to have significant potential and to be able to add large quantities of new reserves for exploration, especially due to the thickness of the reservoirs. As a matter of fact, discoveries were recently announced in the Iranian Zagros Foldbelt (Sefid Ba’ghoun (4.4 tcf), and Halegan (8 tcf), in the Arabo-Persian gulf (Forouz (17.5tcf), Karan (9 tcf), Arabiyah), which are attributed to this target.

Although it cannot be considered as a new exploration target, there is still a number of identified but undrilled prospects at this target, especially in the Iranian Zagros Foldbelt, in the Central Arabian uplifts and in salt related structures of the Arabo Persian Gulf. There are also large areas virtually unexplored in the Western Iraqi desert and in the Rub’al Khali basin.

In addition to this target, since the beginning of the century there has also been a move in the exploration of the Petroleum system in Arabian Peninsula to the deeper clastic reservoir of the Lower Paleozoic section. These deeper levels proved to add rich hydrocarbon resource, also sourced by the Silurian Qusaiba “hot shale”. It contained oil and gas in various reservoirs throughout Central, Northern, and Eastern Saudi Arabia, but also in Bahrain, Turkey, Jordan and Iraq.

Recent discoveries from this Lower Paleozoic clastic interval include Sirayyan, Sanaman, Dirwazah or Nujayman (Lower Permian) or Kassab & Rabib (Devonian). Most of the discoveries are situated in the Greater Ghawar uplift area, but this play is also recognised to be present in the Arabo-Persian Gulf, offshore UAE, Saudi Arabia and in Bahrain. There are most likely still quite a lot of discoveries to make in these layers, whether in already identified structures undrilled at these levels or in new targets.

Finally, a significant effort was made towards the exploration and understanding of tighter Lower Palaeozoic succession. This was thought to be able to hold huge quantities of hydrocarbon (mainly gas), in this pile of thousand meters of still poorly known siliclastic succession. The nature of the clastics varies considerably across Arabian Peninsula, either in nature (depending on depositional settings and erosive events) or in properties (from conventional properties to unconventional tight properties).

Near future exploration will likely be targeted to validate this expected potential. The discovery of new plays and large reserves will, however, be strongly linked to the local policies and international environment.

In particular, the last exploration results in the Rub al Khali, opened to IOC’s for exploration since 2003, proved largely disappointing for the four ventures, finding no new commercial quantities of gas. This raised concerns about the diminishing rate of increase of the gas reserves of Saudi Arabia. Although 3 of the 4 ventures decided to embark on new periods (exploration or appraisal), it is considered that without significant incentives, exploration won’t be sustained, especially given the high exploration and development costs in this harsh environment. Exploration might only be spurred by raising the gas prices and return conditions to attract more investment.

In other countries, the problem is different. In Iraq, there is a strong commitment to the acceleration of the production of the already discovered fields, and a primary focus on the oil-prone areas of the Zagros and Mesopotamian basin. Gas exploration, especially to the more desertic areas of the West is likely to be deferred for some time.

In Iran, there is quite a lot of hurdles that are delaying any futher projects. The present international sanctions prevent any major investment in the country, and although there are already numerous giant gas discoveries identified, the country lacks the financial capacity to translate it into developments.

#### Australian Offshore

Australia is proving from the last ten years to be one of the most prolific basin for gas worldwide. Year after year, new giant fields are discovered onshore, accounting for 50tcf of new reserves in the last decade. The main focus for exploration remains the western Australian sedimentary basins, in particular the Jurassic and Triassic sandstones of North Carnarvon Basin, the Jurassic and Permian targets in the Perth Basin, but attention is also currently concentrating on Cretaceous and Triassic formations in the Browse Basin and on the Permian formations in the Bonaparte Basin.

Offshore exploration already identified more than 160 Tcf of gas in the Carnarvon, Browse and Bonaparte Basins. Major recent finds include Poseidon (7tcf), Acme, Alaric, Brederode, Kentish Knock, Greater Gorgon Area (11 fields, including the wildcat wells of Geryon-1 (1999), Orthrus-1 (1999), Urania-1 (2000), Maenad-1 (2000), Jansz-1 (2000), Io (2001), Chandon-1 (2006), and Achilles (2009), Satyr (2009)) estimated at more than 40tcf or Burnside (1.5tcf) discoveries in the Carnarvon basin but also Ichtys (12.8tcf) in the Browse basin.

Western Australia will certainly continue to attract this high interest for the next 20 years. This interest is sustained by a concentration of favorable conditions.

The political risk of the country is considered as one of the lowest, providing high visibility on the investments. The authorities set in place a clear fiscal regime, designed to encourage exploration, in particular in frontier basins. In addition, there is a policy of transparency and sharing of information that promotes innovation and encourages new ideas for exploration.

Finally, Western Australia’s proximity to Asian markets places it in an ideal position to meet growing expected gas demand. This demand was forecasted because of the increasing developments and needs of the Asian countries (China being the first), but was lately reinforced by the probable consequences of the Fukushima accident, shifting energy policy away from Nuclear Power.

To meet this future demand, last years saw fierce competition between operators to launch LNG projects. In particular we can cite Gorgon, Pluto, Browse LNG, Wheatstone projects…. We can see these projects as opportunities for exploration in the area, as supply is following the increasing demand, still expected to be rising in following years. This situation is particularly exemplified by the latest major LNG gas purchase agreements signed by Sinopec and South Korea, of 85b$ each. The densification of these LNG projects will concur to unlock the vast stranded potential of Australia, as commercial developments were blocked by the lack of infrastructures and the distance to export solutions.

Another favorable factor is the development of new Floating LNG technologies that are designed to produce gas fields that are either too small, or too far away from the shore to be economically viable to be developed by a classical onshore LNG facilities. Shell’s Prelude/Concerto project and Santos’s Bonaparte projects are currently under way. These new technologies will certainly allow to reconsider what is currently considered as stranded reserves (140 tcf according to CSIRO in Australia).

#### East Africa

East Africa has been emerging as a new frontier area for gas exploration in the very recent years. Previously, despite some early gas discoveries in the 1960’s, onshore Mozambique and offshore Tanzania, the limited internal markets of the area, and the position of the countries away from the traditional export routes, explains the lack of interest of major companies in the area.

Progresses of deep water drilling technologies enabled the operators to tackle basins that were considered too deep to be explored before. This extension of the exploration zone area created new opportunities.

The East African prospectivity image changed as Anadarko, despite apparently looking for oil, encountered multi tcf of dry gas reserves in 2010, in its 1st wildcat offshore Rovuma basin (Windjammer) in Mozambique, at the border with Tanzania. It was followed by close Barquentine and Lagosta discoveries (total Windjamer complex announced as 15-30 tcf by Anadarko) and by the Tubarao discoveries in other Tertiary levels, that expands the prospective layers. This innovative exploration risk was supported by several years of studies and the identification of a sufficient lead portfolio that was worth de-risking. As a result Anadarko’s senior vice president for Worldwide Exploration, described Windjammer as a “true rank wildcat” that de-risked a substantial portion of approximately 50 leads and prospects that the company has identified across its 2.6-million-acre position in the basin.

These significant reserves found enable Anadarko to concentrate on this new play and to award contracts for pre-FEED (front-end engineering and design) work for a prospective LNG plant according to KBR. The target for a final investment decision is 2013

These recent Mozambique discoveries, large enough to be commercial, created a regional acceleration of investment in exploration from already installed players (Dominion Petroleum, Artumas, Aminex, Origin Oil, Maurel & Prom, Ophir) and began to attract interest from other IOC. In particular, ENI and Statoil are preparing exploration campaigns in Mozambique blocks.

The prospectivity of the basin also extends to the Northern area, in Tanzania, where BG and Ophir struck discoveries. Two discoveries (Pweza and Chewa) in block 4 appear “soundly economic as a floating LNG development” according to BG. This was followed by Chasa discovery in April 2011, in Block1 extending the prospective acreage. Strategic moves are currently made, in particular Exxon Mobil in late March 2010 acquired a 35% interest in the Tanzanian deep-water Block 2, operated by oil company Statoil. Petrobras is also expected to launch an offshore exploration campaign end of 2011. The competition for acreage is expected to be fierce in the future round for offshore exploration, that it has been deferred to 2012 by Tanzanian authorities including deepwater blocks from 1200 to 3500 m water depths.

Finally, the operators are positioning further north, in order to expand the exploration to the under-explored areas of the Kenyan waters. Anadarko already positioned in 2010. BG and Dominion announced psc signatures in 2011 with Kenyan government for offshore area in 2011. Other companies are farming-in offshore areas (Total).

After the initial moves from the operators, and according to a research note by Citigroup, the East Africa region is expected to experience a strategic pick-up in farm-ins and mergers and acquisitions to consolidate smaller players. It already began in 2011, but is expected to grow further (Apache, and Shell bid on Cove). It is likely that major exploration campaigns will be launched in the years to come following the consolidations, and increasing investment capacities, of the groups. Still, the main bottleneck is the lack of major export solutions, but as the gas discoveries begin to pile up in the different countries in the area, it is raising the expectation of possible solutions in the near future. Floating LNG concept currently developed for Australian assets might be finding another market for development.

All this news and activity in the last two years has already changed the status of the area to a high growth and potential zone. Given the low present number of exploration in the area, this area should still be considered as a frontier zone, but the knowledge of the area will most likely evolve rapidly.

#### Central Asia

The Central Asian region, and in particular the Caspian Sea region, has been expected to become one of the most promising area for world gas exploration since the 1990’s. Indeed, after a first period of declining exploration and production following the collapse of the Soviet Union, there was an upward trend of exploration and production in the area. Some countries managed successfully to attract foreign investment (in particular Azerbaidjan and Kazhkstan), which led to world class discoveries and major project developments. We can cite Karachaganak, Tengiz, Shah-Deniz as one of these world scale projects launched since the collapse of FSU.

In support of the development of this zone, new export routes have already debottlenecked the Caspian Area. The Caspian Pipeline Consortium (CPC) capacity between Tengiz and black sea coast is planned to be doubled by 2015. However the area still needs further developments and expansion of direct export routes to Europe. Nabucco, ITGI, TAP pipeline projects or AGRI (LNG) project via the black sea that are currently discussed, are such solutions, but they are still not fully concrete and require strong state support.

Although the area is perceived as a fantastic area for exploration, the situation is quite contrasted in the countries of this region, depending on the maturity of the exploration area, and the opening to foreign investment.

Prior to 1999, exploration in offshore Caspian area was very limited, with only a few activities close to the coast of southern Dagestan. First major exploration began in 1999, with discoveries of Khvalynskoye and Yuri Korchagin, rapidly followed by Rakushechnoye, Sarmatskoye and Filanovsky. Accurate reserve estimates are lacking in the area, but it is described as 'significant'. According to BP , proved reserves in the area are in the range of 450 tcf.

Kazakhstan is one of the most promising countries in Central Asia, and considered as rather under explored. Although several giant oil discoveries were made in the Northern Caspian area, natural gas exploration has clearly lagged behind oil due to the lack of domestic pipeline infrastructure, linking the western gas producing regions to the eastern consuming (industrial) regions. Gas potential in this country should be considered as promising, presently sustained by key partnerships with Russia and China. Major undiscovered resources should be considered to be offshore, and dedicated to major companies due to the development scale, but onshore exploration and appraisal activities are benefiting from smaller players involvement (BNBn Tethys Petroleum, Max Petroleum…p) and are still adding significant resources.

In Azerbaijan, historic exploration focused on onshore plays that are now thoroughly explored. The remaining undiscovered hydrocarbons should mostly be located offshore, in very challenging environments. In particular, the reservoirs from deltaic origin are highly overpressured due to the very quick deposition of the overlying sediments. In addition, the depths to reach are very important, requiring high technology drilling.

The late exploration results were somewhat mixed. Of the 10 deep offshore wells drilled by foreign companies in the last 10 years, only one major discovery had been made (Shah Deniz estimated between 22.5 to 42 Tcf). In contrast, numerous structures were disappointing (Araz Deniz, Oguz, Lenkoran Talysh, Kurdashi, Inam,…). The conjunction of high costs and limited success explains the low number exploration in the area. The difficult geological environment necessitates state of the art drilling and completion technologies. Even with that, some of the targets could not be reached (eg. Inam, Yanan Tava and Zafar Mashal) and some of the structures remain yet to be properly tested. It has to be noted that the recent announcement on Absheron-2X might add another significant exploration success.

In Turkmenistan, the latest decade results were less spectacular with 200 wells finding only 5.3 Tcf in 17 gas fields, until discovery and reassessment of the giant South Iolotan field (est. around 21 tcm (More than 700 tcf), although a lot of uncertainty still exists on the proper reserves). It allowed the country to jump as one of the world’s new gas reserve holder. The S. Iolotan reserves, along with the developments of the reserves in the sub-salt Jurassic layers, allowed to consider major export project, directed to the East. The Turkmenistan-China gas pipeline progressed with first stages of construction of the Uzbek and Kazakh sections.

There is a question as to whether other countries like Kyrgyzstan and Uzbekistan might become major players in the area. The reserves are presently considered as of a lesser extent of their neighbors. Uzbekistan is however having a good position, being the 3rd largest producer of natural gas in the FSU after the Russian Federation and Turkmenistan. According to the BP Statistical Review of World Energy 2011, Uzbekistan’s proven natural gas reserves at 55 tcf, mainly in the Amudarya basin and the Murabek area in the southwest of Uzbekistan. Recently exploration focused on the Aral sea region, with first announced successes.

Kyrgyzstan is also seeking development of its gas reserves with involvement of foreign companies. Successes of the exploration in these two countries are, however, dependant from the local incentives, to open market, to promote private sector and to establish convertibility of currencies.

#### Discussion

The areas reviewed in the preceding pages are spanned all over the world. There is potential remaining in many locations and the recent major discoveries announced in the recent years highlight that reserve replacement can be sustained by exploration for some time.

As frontier or recently identified areas may be capable of adding substantial reserve growth, it should however be clear that a large part of the potential is situated in existing proven plays, and for a large part situated in deepwater. Gulf of Mexico, West Africa (and in particular Nigeria and Angola), Egypt, Brazilian Santos and Campos basins will continue to be the key drivers for exploration performance, for Gas and Oil. Due to these areas, importance of deepwater E&P will likely to be increasing in the next twenty years (89% of Resources found in 2010 were offshore).

Moreover, Frontier Exploration may create new opportunities, but many of the recent discoveries of significant size were made in areas that are already identified as well endowed with gas resources, as in Northern Western Siberian area, Australia, Iran or Norway.

The challenge of Frontier Exploration is not only to be able to find new resources in difficult or poorly known locations, but then to be able to successfully translate those discoveries into production, while being in competition with historic areas. A regional abundance of gas reserves may be impacting negatively on the development of new areas, as competition for sales contracts is increasing with the expansion of LNG global market. In addition, Frontier areas may suffer from the time span to be able to set up a gas infrastructure to export the gas to the consuming areas. This will be an issue for the East African development, but may also be the case for some remote Australian projects.

In addition, conventional frontier exploration is facing competition from unconventional sources, either shale gas, tight gas or Coal Bed Methane. These new gas supplies may impact locally the markets, as Shale gas in US, providing a variety of supply solutions.

As a fact, according to Wood Mackenzie, a large part of the gas reserves that were discovered in the last ten years are yet to be concretized. And for example, less than 5tcf were already produced on the 170 tcf discovered in 2000.

As a conclusion, Exploring in new areas may be both extremely exciting and valuable, being able to change completely the face of a company or even a country. However, the success of frontier exploration relies on the capacity to bring to the market the discoveries. It is therefore strongly linked to the capacity to gather rapidly a pool of enough reserves to be able to proceed to development. The projects in Frontier areas always face technical challenges, either due to lack of infrastructure, considerable water depths, high pressure / high temperature reservoirs or difficult targets. These impose economical threats to the operators that are investing in these areas.

The success of Frontier exploration is therefore dependent on new technological innovations, that allow to face these challenges by drilling deeper and safer, and by designing creative production facilities. It is also largely dependant on the political support of the countries, which should be establishing the necessary incentives to take risks.

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## Appendices

## A List of Tables

## B List of Figures

## C Glossary and Acronyms