**Arab Energy Club**
Beirut, 8 January 2011

# MENA NATURAL GAS

## Reserve Depletability and Resource Prospectivity (*)

(*) The narrative for this presentation has been published concurrently in APICORP's *Economic Commentary* Vol. 5 No. 12 and *MEES* dated 27 December 2010, under the title "MENA Natural Gas: A Paradox of Scarcity Amidst Plenty"

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# OIES's MENA Gas Book: Main Findings and Conclusions

- "… rising concern about critical gas shortages in many countries in the region due to rapid growth of domestic consumption of natural gas and a muted and delayed gas supply response"
- "… a regional default model seems to be emerging based on increasing natural gas supplies through exploration and development [E&D]"

# OIES's MENA Gas Book's Conclusion Begs Two Key Questions

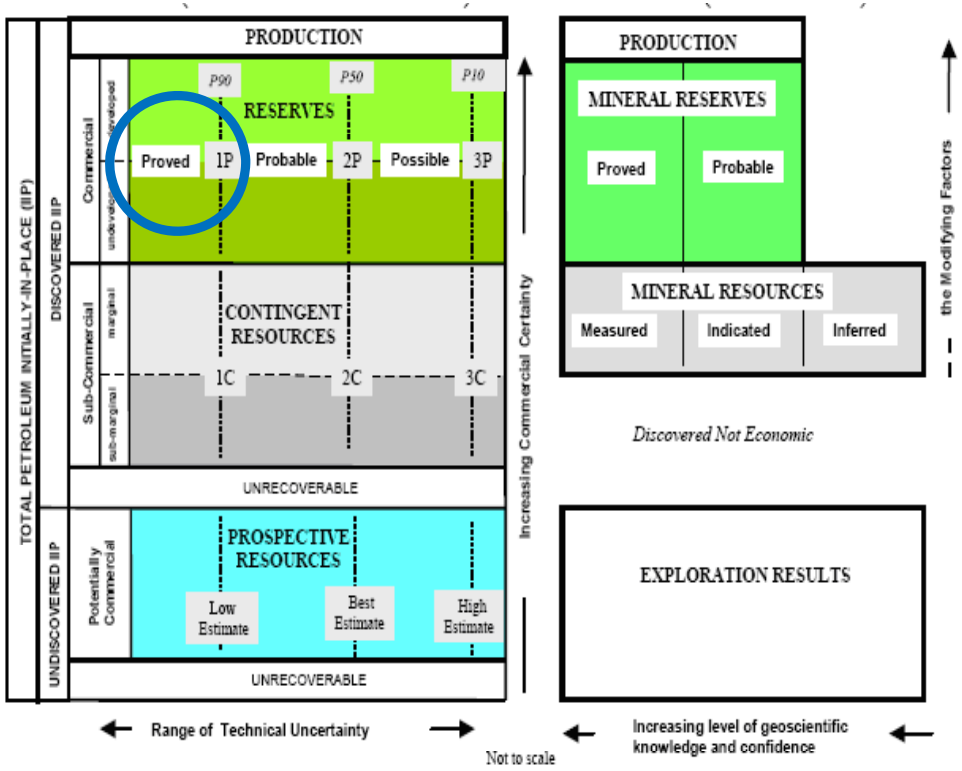
- How fast are MENA natural gas reserves depleting and in what way the resulting supply pattern is evolving?
- Is the likely size of undiscovered resources high enough to create sufficient opportunities for E & D?

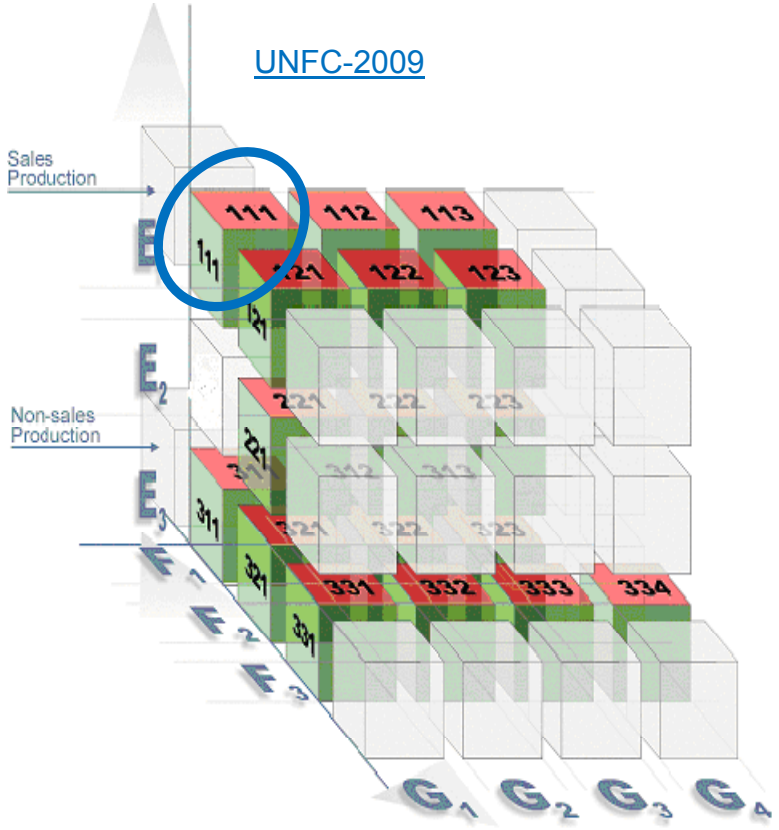
# Outline of Presentation

- Assessment framework and origin of data
- Part I: Reserves depletion and supply pattern
  - *Reserve replacement (RRR metric)*
  - *Reserve life (dynamic R/P metric)*
  - *Supply pattern (OST metric)*
- Part II: Undiscovered resources and potential for E & D

# Assessment Framework and Data (I)

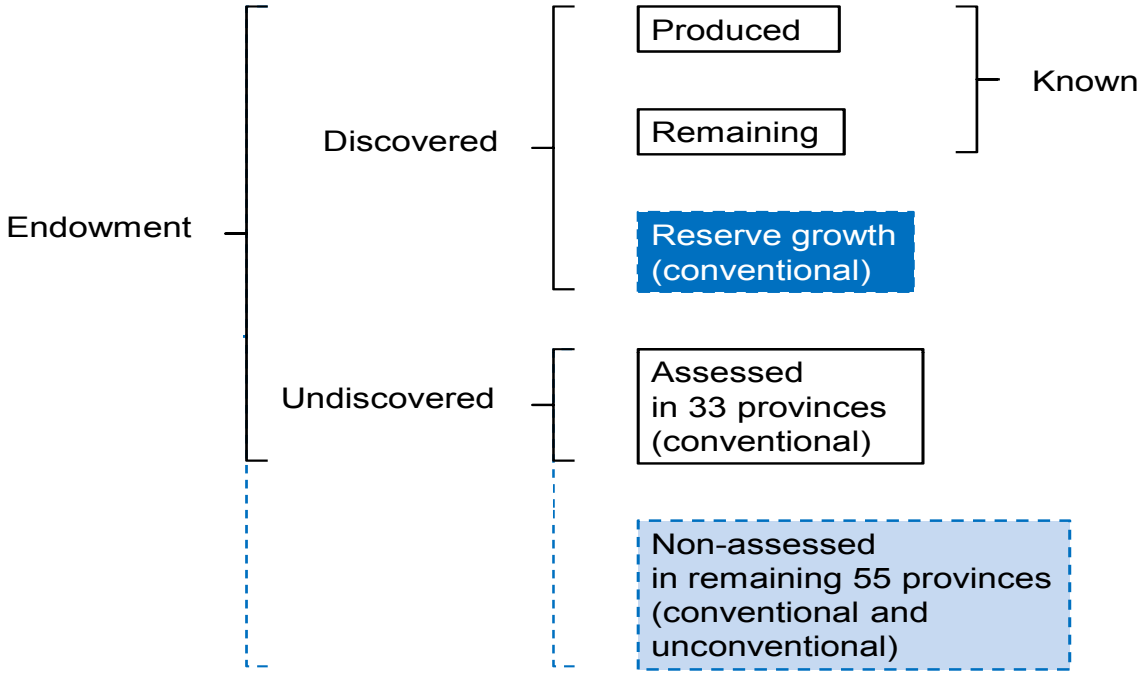
PRMS (SPE/WPC/AAPG/SPEE)-2007 | CRIRSCO (Minerals)-2004 | UNFC-2009




Proved reserves (1P/P90 or E1F1G1): BP Statistical Review of World Energy
To avoid the gap of Probable (112) and Possible (113) reserves,
we adopt the concept of “reserve growth”

# Assessment Framework and Data (II)
# Undiscovered Resources and Reserve Growth




APICORP Research's interpretation of USGS framework

US Geological Survey data for undiscovered resources in 33 MENA provinces

Own inference of undiscovered resources in 55 remaining MENA provinces

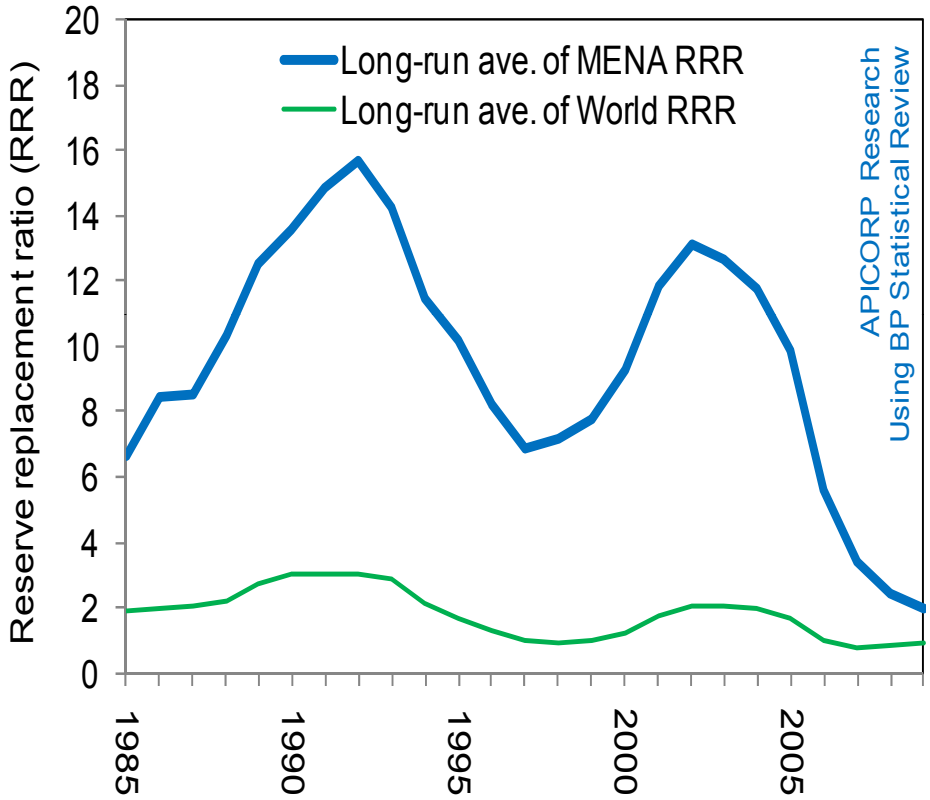
Own interpretation and adaptation of "reserve growth"

# PART I

# Reserves Depletion and Supply Pattern

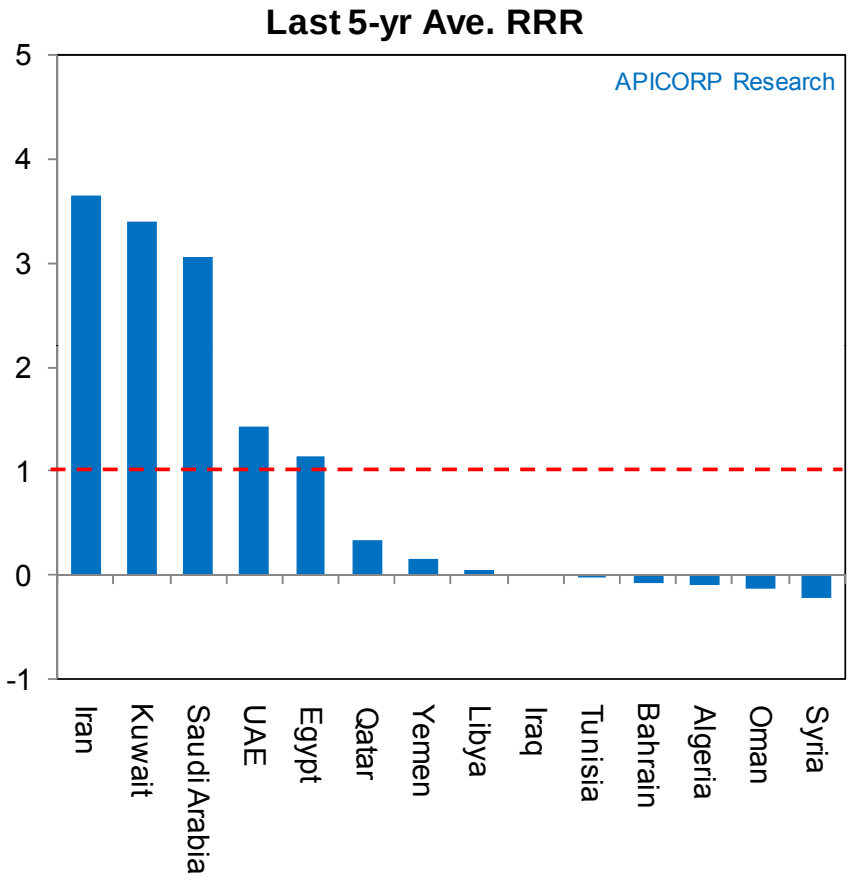
# MENA Reserve Replacement Ratio (RRR)

- Historical high RRR moving average
- Two prominent peaks:
  - 15.8x (1580%) in 1992
  - 13.1x (1310%) in 2002
- Recent fall off to less than 2x (200%): Is MENA running out of reserves?



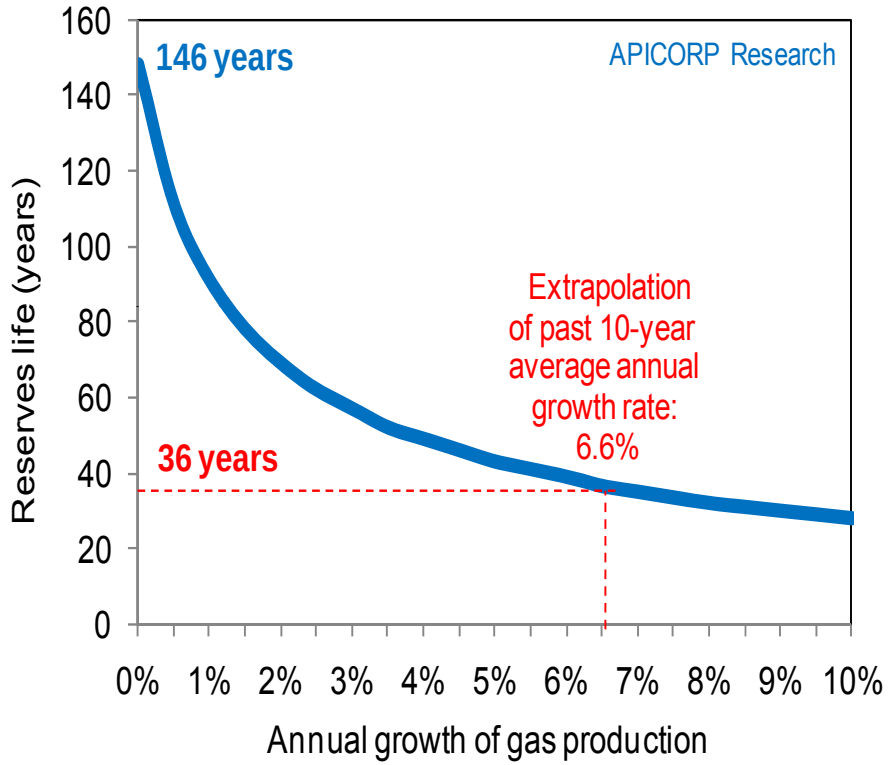
# Countries' Reserve Replacement

- Previous aggregates conceal considerable country differences
- Iran, Kuwait, Saudi Arabia, the UAE and Egypt, have continued to replace a large portion of their extracted reserves
- By contrast, Qatar, Yemen, Libya, Iraq, Tunisia, Bahrain, Algeria, Oman and Syria, have failed to keep pace with production



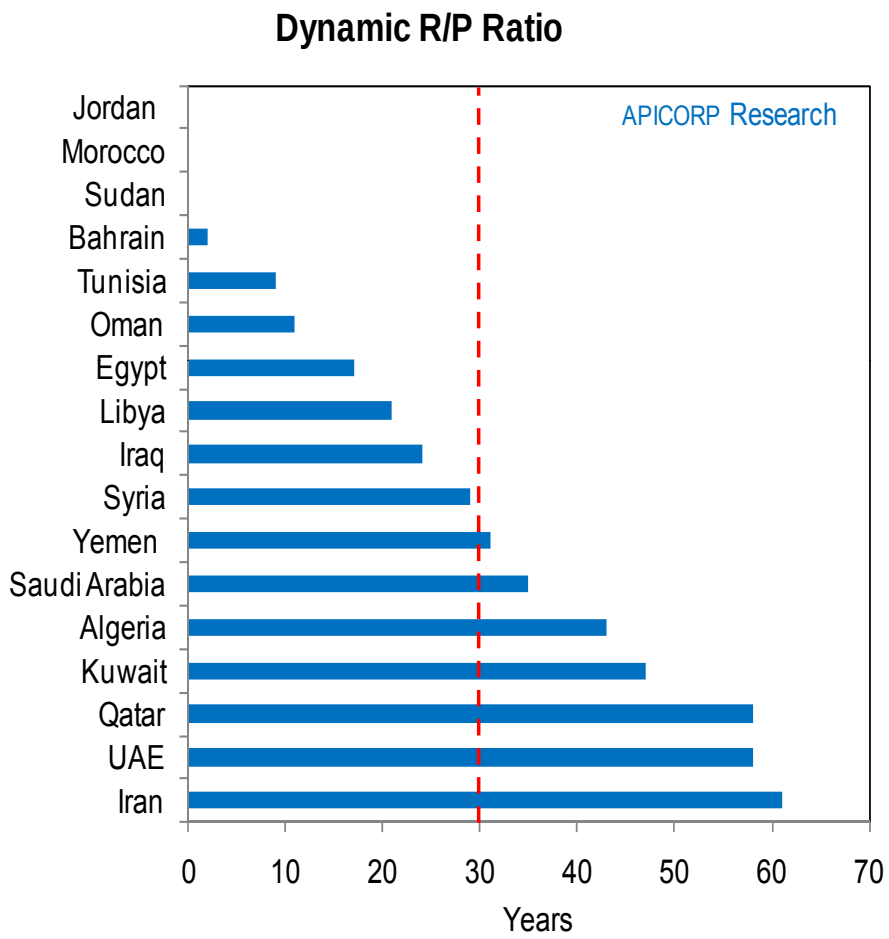
# MENA Reserve Life (Dynamic R/P)

- R/P ratio can provide a practical measure of reserve life
- Currently amounts to 146 years for the region compared to 63 years for the world
- A non-constant assumption about depletion rates shows how the ratio can dwindle rapidly with future production growth



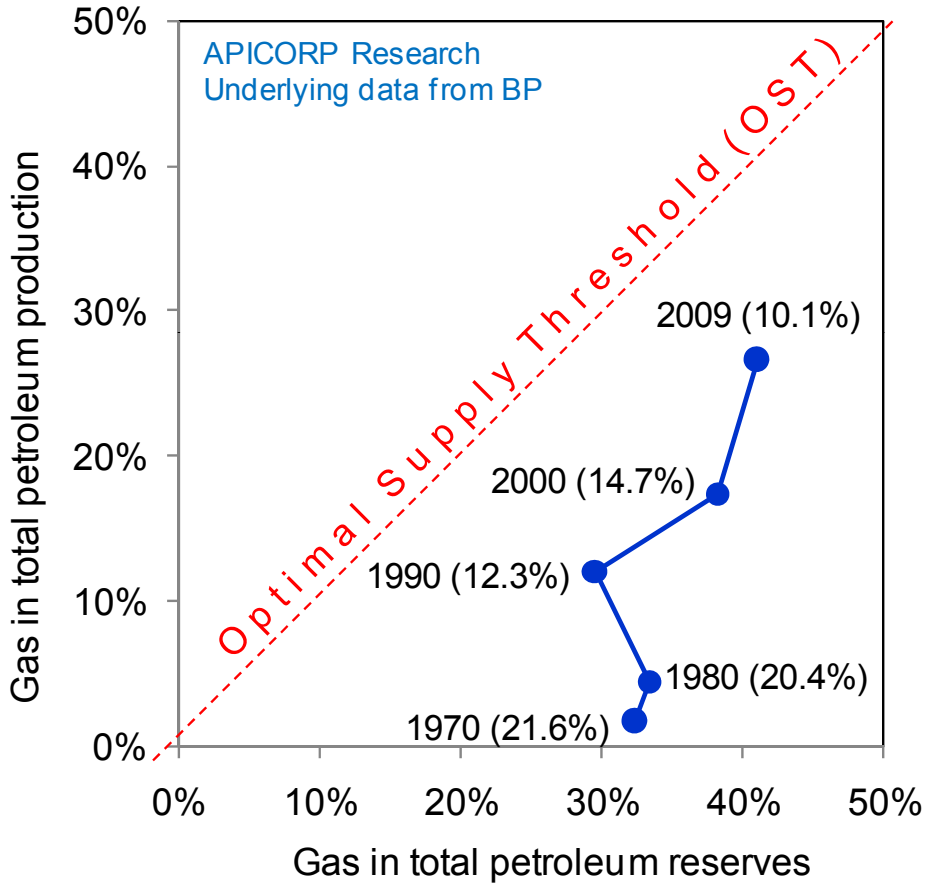
# Countries' Reserve Life (Dynamic R/P)

- As with the RRR metric, R/P ratio is subject to significant variations across countries
- Ratios for Iran, the UAE, Qatar, Kuwait, Algeria and Saudi Arabia are all higher than 30 years
- Apart from Syria, which is at the limit of this critical time horizon, all other countries are beneath it



# MENA Supply Pattern

- A further attempt at gauging the depletion of MENA reserves is by measuring the trend towards an optimal supply threshold (OST)
- Progress made by the region as a whole, decade after decade since 1970, shows a slow convergence towards the OST dashed line



# Countries' Supply Pattern

- The 2009 cross section confirms previous aggregate trend
- Keeping progress towards OST should be encouraged
- Unless perceived too expeditious as a result of demand growing faster than additions to reserves.

| | Gas reserves over petroleum reserves | Gas production over petroleum production | Distance to OST |
|---|---|---|---|
| Yemen | 0.55 | 0.21 | 23.8% |
| Qatar | 0.86 | 0.54 | 22.6% |
| Algeria | 0.71 | 0.45 | 18.8% |
| Iran | 0.59 | 0.36 | 16.5% |
| Syria | 0.43 | 0.22 | 15.1% |
| Oman | 0.54 | 0.36 | 13.2% |
| Egypt | 0.77 | 0.60 | 11.8% |
| Tunisia | 0.69 | 0.59 | 6.9% |
| Iraq | 0.16 | 0.10 | 4.2% |
| UAE | 0.31 | 0.25 | 3.9% |
| Libya | 0.19 | 0.14 | 3.3% |
| Saudi Arabia | 0.17 | 0.13 | 3.0% |
| Kuwait | 0.11 | 0.08 | 1.6% |
| Bahrain | 0.86 | 0.92 | -4.3% |
| Total MENA | 0.41 | 0.27 | 10.1% |

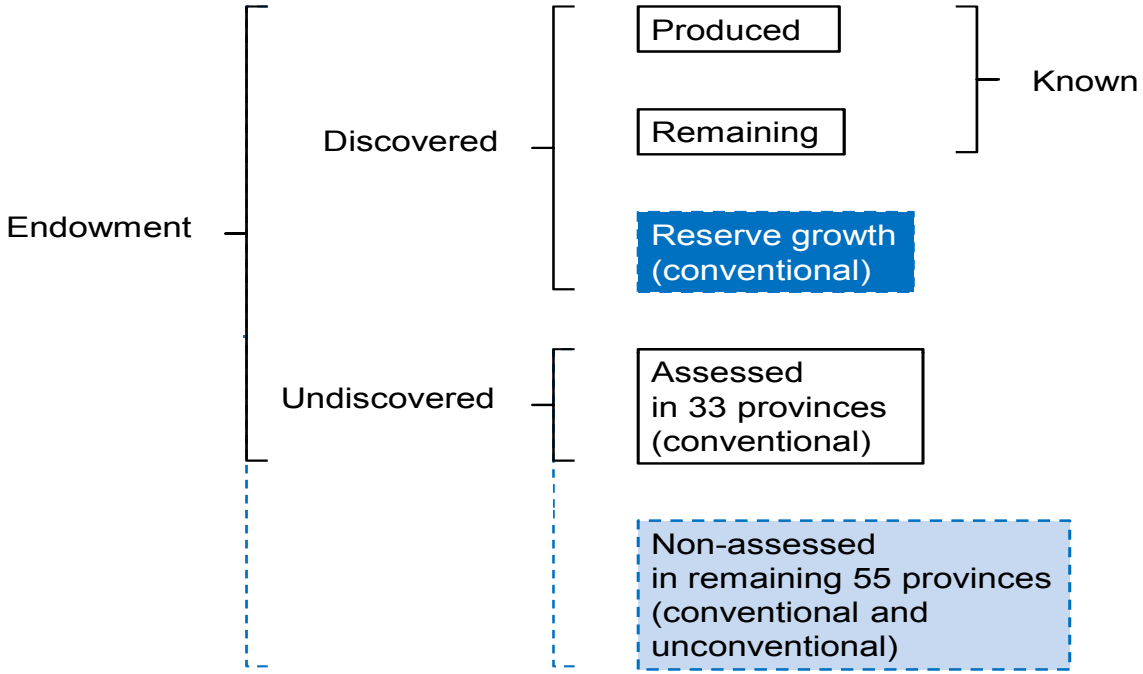
APICORP Research using data from BP 2010

# PART II

# Undiscovered Gas Resources

# and the Potential for E&D

# Assessment Framework and Data
# Undiscovered Resources and Reserve Growth

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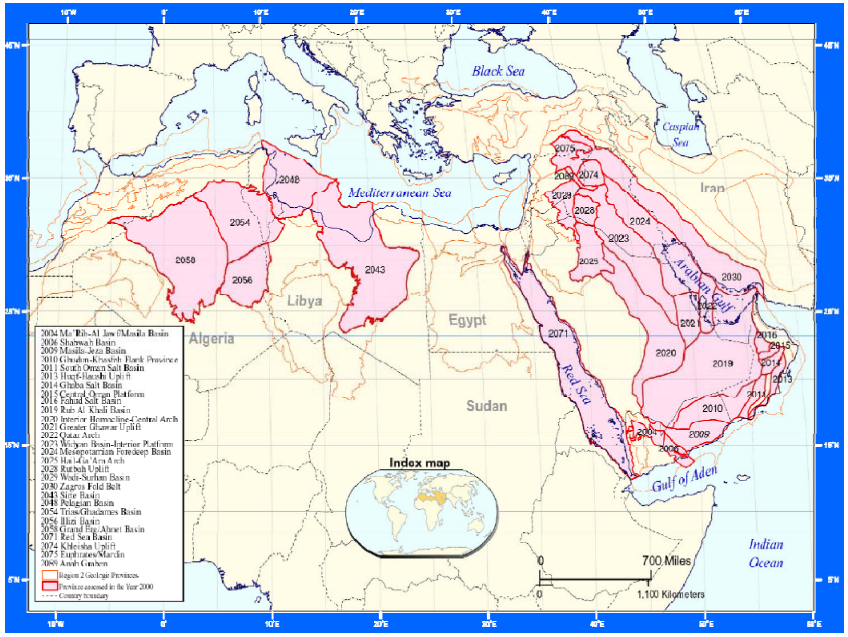
# USGS (2000) MENA Region 2

- USGS concentrated on producing provinces or those deemed highly prospective
  - Did not include Nile Delta and East Mediterranean, which proved successful
- Focused on conventional gas
  - Overlooked tight, deep or contaminated gas areas developed since in Algeria, Saudi Arabia and the UAE



# USGS-2000 Region 2
# Undiscovered Natural Gas in 33 MENA Provinces

**Middle East and North Africa, Region 2**

**Assessment Results Summary**

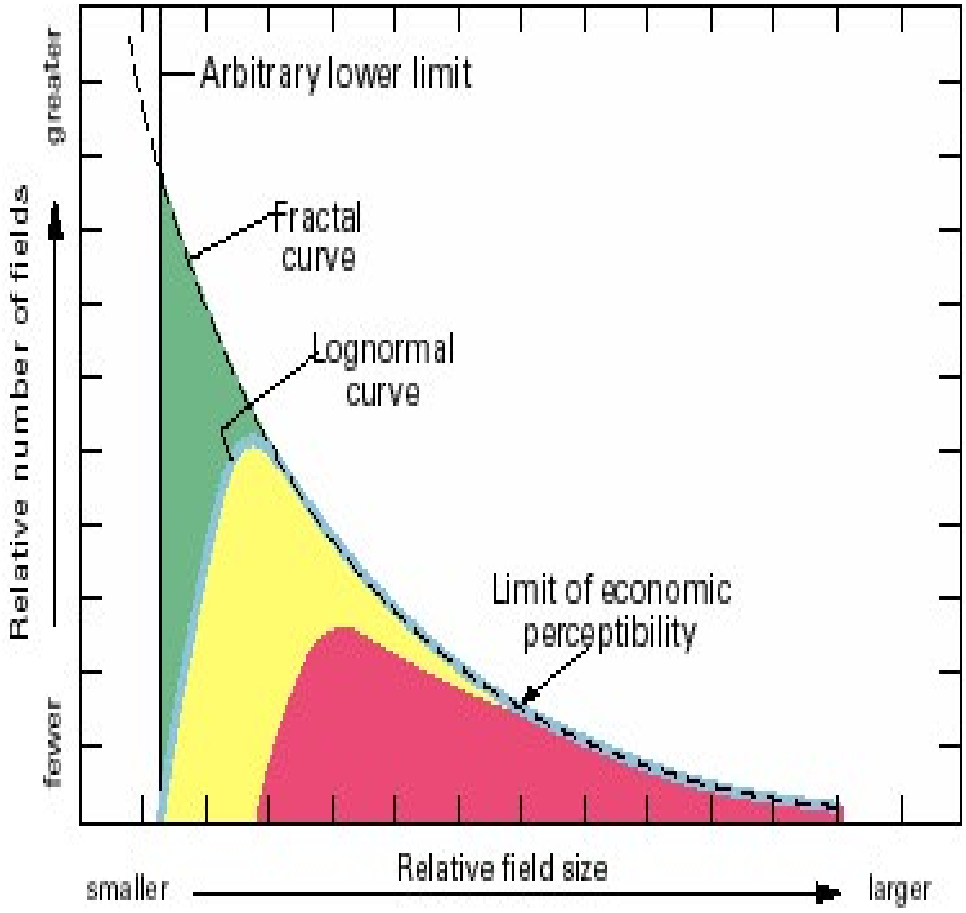
[MMBO, million barrels of oil. BCFG, billion cubic feet of gas. MMBNGL, million barrels of natural gas liquids. Prob., probability (including both geologic and accessibility probabilities) of at least one field equal to or greater than the minimum assessed field size. Results shown are fully risked estimates. For gas fields, all liquids are included under the NGL (natural gas liquids) category. F95 represents a 95 percent chance of at least the amount tabulated. Other fractiles are defined similarly. Fractiles are additive under the assumption of perfect positive correlation. Shading indicates not applicable]

| Code and Field Type | Prob. (0-1) | Undiscovered Resources | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oil (MMBO) | | | | Gas (BCFG) | | | | NGL (MMBNGL) | | | |
| | | F95 | F50 | F5 | Mean | F95 | F50 | F5 | Mean | F95 | F50 | F5 | Mean |
| 2 | **Total: Middle East and North Africa** | | | | | | | | | | | | |
| Oil Fields | 1.00 | 73,288 | 215,651 | 432,178 | 229,882 | 90,494 | 286,235 | 678,796 | 328,248 | 3,947 | 13,571 | 33,943 | 15,560 |
| Gas Fields | | | | | | 334,887 | 982,973 | 1,928,100 | 1,040,684 | 20,029 | 61,249 | 128,731 | 66,152 |
| Total | 1.00 | 73,288 | 215,651 | 432,178 | 229,882 | 425,371 | 1,278,208 | 2,607,896 | 1,369,933 | 23,976 | 74,820 | 162,673 | 81,747 |

| | Mean (tcm) | Share (%) |
|---|---|---|
| Associated | 9.3 | 24 |
| Non-associated | 29.5 | 76 |
| Total gas: | 38.8 | 100 |

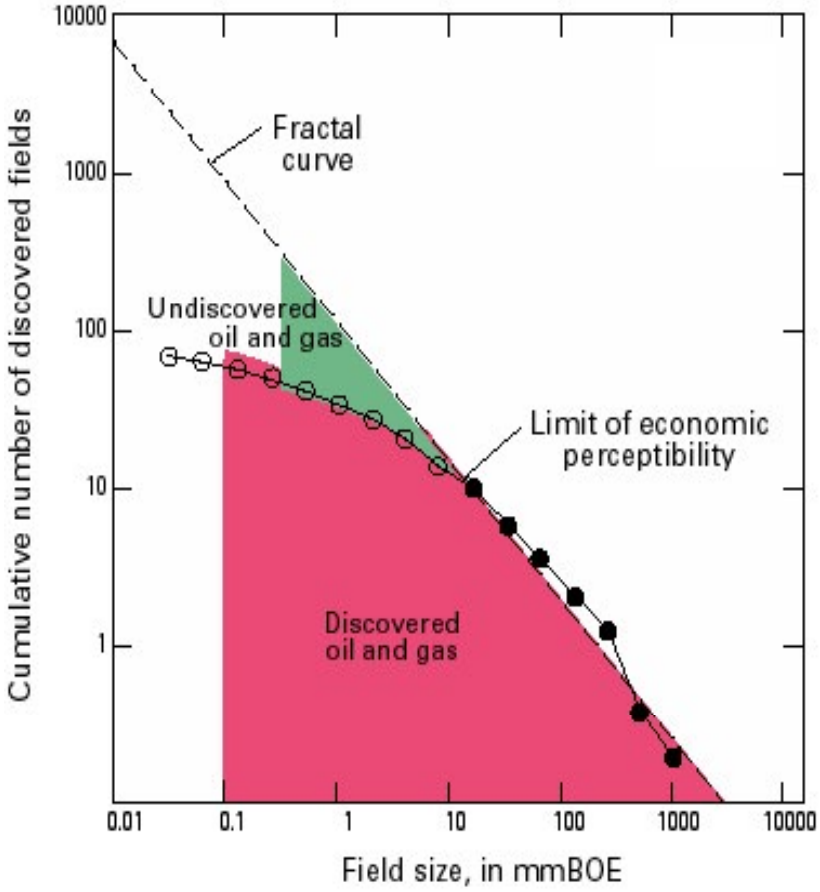
# Assessing Resources (I)
# Traditional Size-Frequency Distribution Models

- In lognormal density distributions, modes (peaks) shift towards smaller accumulations
- A lower bound tends to push lognormal model towards a power law model (hyperbola)



# Assessing Resources (II)
# Fitting a Fractal or Power-law Distribution

- The “limit of economic perceptibility” in the one between black and clear spots
- A fractal can be fitted to discovered accumulations larger than the economic perceptibility (black spots)
- Extrapolated to smaller accumulations, the fractal overestimate undiscovered resources



# Assessing Resources (III)
# Aguilera's Variable Shape Distribution (VSD)

- VSD does not presume any form of the distribution function, but allows actual data to determine the relationship
- VSD is the solution of a nonlinear least square regression model

$$\text{Min}_{\{Vx,\ \partial p,\ Vs,\ \Psi,\ S\}} \sum_{i=1,n} (V_i - \tilde{V}_i)^2$$

Subject to constraints on 5 parameters

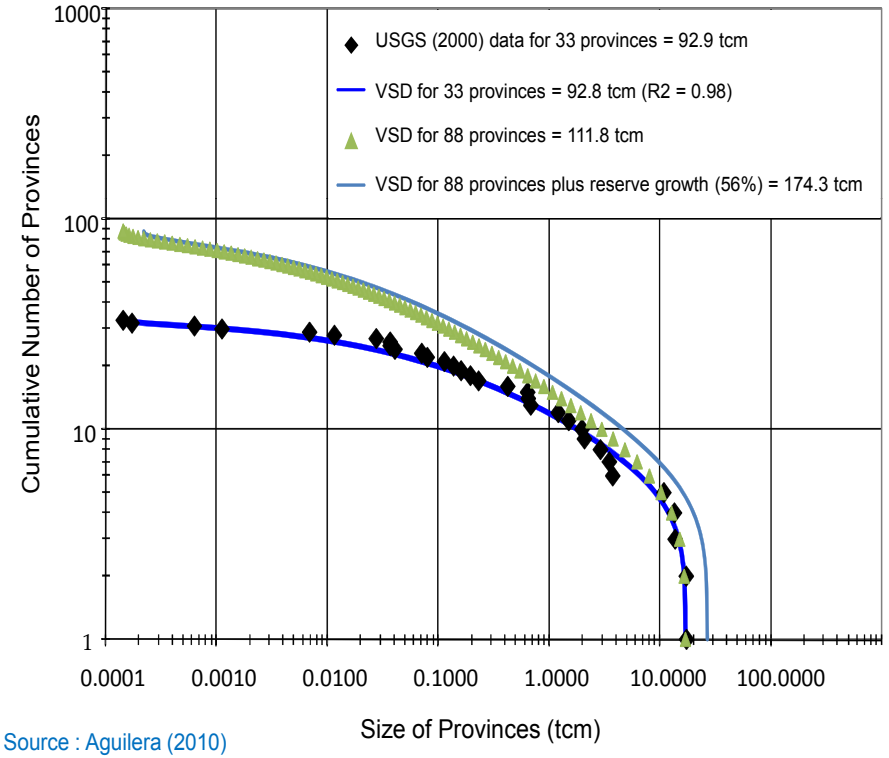
Vx: Maximum volume given by the Pareto straight line

$\partial p$ : Slope (~ fractal slope); Vs: Approximate deviation volume;

$\Psi$: Separate ratio ; S: Severity exponent (steepness).

# Assessing MENA Resources/Endowment Variable Shape Distribution (VSD)

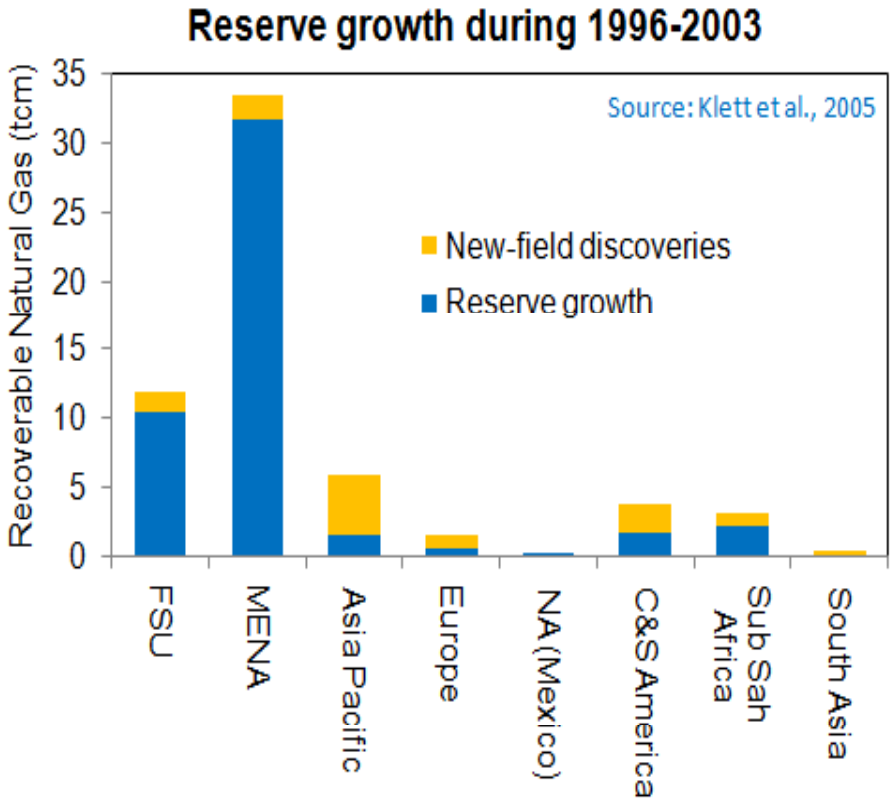
- 93 tcm - USGS (2000) for 33 provinces (area below black diamonds, or correlation-fitted line)
- 112 tcm - VSD model for 88 provinces (area below green triangles)
- 175 tcm – VSD88 plus 56% reserve growth (area below light blue, outer line)




Source : Aguilera (2010)

# Reserve Growth : Extending a USGS Concept

- "Reserve growth" originally defined as field growth
- USGS transposes a typical US pattern growth of 56% over a 30-year time span (1995-2025)
- In our case, the (conservative) rate of 56% is used to "grow" both known reserves and undiscovered volumes



# Resulting MENA Gas Endowment and Undiscovered Volumes

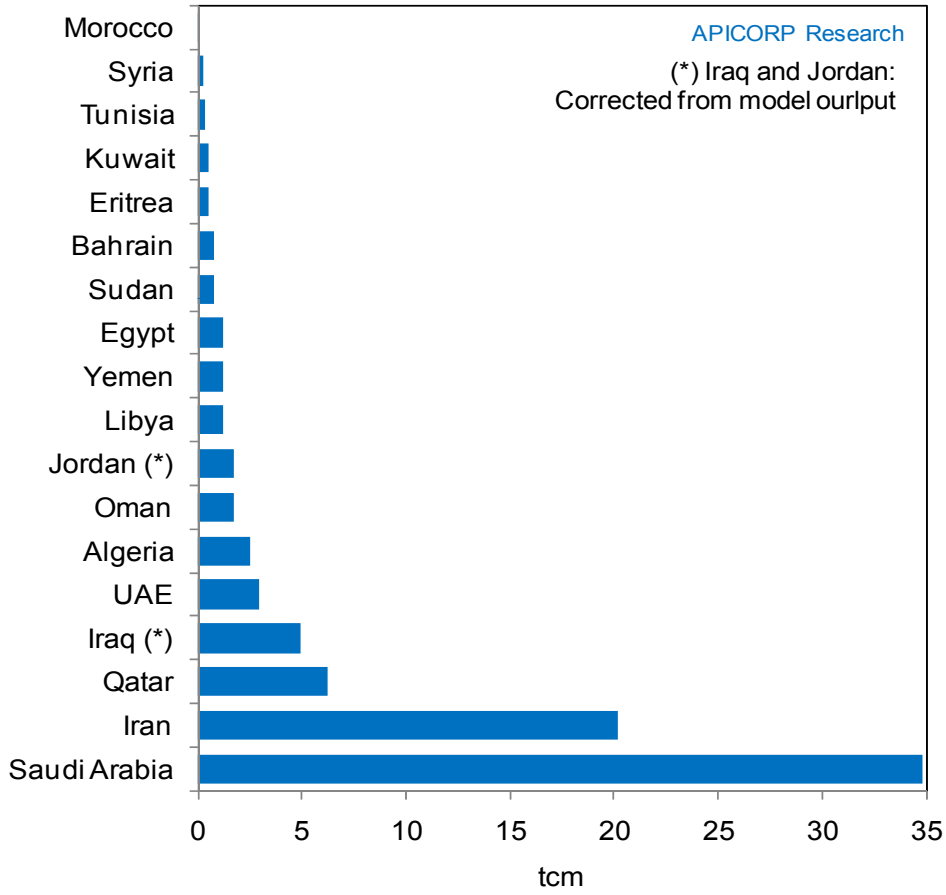
| | 1. Cumulative production up to 2009 (tcm) | 2. Proven reserves Jan 2010 (tcm) | 3. USGS-2000 Undiscovered resources (tcm) | 4. Weighted average of 1,2, and 3 (tcm) | 5. Resulting weighted shares (%) | 6. Apportion of VSD-88 volumes (tcm) | 7. Endownt after reserve growth (tcm) | 8. Undiscovered resources and volume growth (tcm) |
|---|---|---|---|---|---|---|---|---|
| Saudi Arabia | 1.318 | 7.920 | 19.286 | 12.503 | 25.2% | 28.3 | 44.1 | 34.8 |
| Iran | 1.737 | 29.610 | 8.909 | 14.614 | 29.5% | 33.0 | 51.5 | 20.2 |
| Qatar | 0.697 | 25.370 | 1.164 | 9.155 | 18.5% | 20.7 | 32.3 | 6.2 |
| Iraq (*) | 0.067 | 3.170 | 3.399 | 2.767 | 5.6% | 5.3 | 8.2 | 5.0 |
| UAE | 0.920 | 6.430 | 1.261 | 2.927 | 5.9% | 6.6 | 10.3 | 3.0 |
| Algeria | 1.868 | 4.500 | 1.387 | 2.505 | 5.1% | 5.7 | 8.8 | 2.5 |
| Oman | 0.243 | 0.980 | 0.956 | 0.845 | 1.7% | 1.9 | 3.0 | 1.8 |
| Jordan (*) | 0.000 | 0.005 | 0.069 | 0.036 | 0.1% | 1.1 | 1.7 | 1.7 |
| Libya | 0.251 | 1.540 | 0.598 | 0.854 | 1.7% | 1.9 | 3.0 | 1.2 |
| Yemen | 0.034 | 0.490 | 0.620 | 0.479 | 1.0% | 1.1 | 1.7 | 1.2 |
| Egypt | 0.582 | 2.190 | 0.579 | 1.117 | 2.3% | 2.5 | 3.9 | 1.2 |
| Sudan | 0.000 | 0.085 | 0.439 | 0.248 | 0.5% | 0.6 | 0.9 | 0.8 |
| Bahrain | 0.249 | 0.090 | 0.468 | 0.306 | 0.6% | 0.7 | 1.1 | 0.7 |
| Eritrea | 0.000 | 0.000 | 0.309 | 0.155 | 0.3% | 0.3 | 0.5 | 0.5 |
| Kuwait | 0.285 | 1.780 | 0.168 | 0.725 | 1.5% | 1.6 | 2.6 | 0.5 |
| Tunisia | 0.064 | 0.045 | 0.202 | 0.127 | 0.3% | 0.3 | 0.4 | 0.3 |
| Syria | 0.089 | 0.280 | 0.144 | 0.180 | 0.4% | 0.4 | 0.6 | 0.3 |
| Morocco | 0.000 | 0.045 | 0.003 | 0.017 | 0.0% | 0.0 | 0.1 | 0.0 |
| Total MENA | 8.404 | 84.530 | 39.961 | 49.558 | 100.0% | 112.0 | 174.7 | 81.8 |

(*) Corrected from model output (more likely higher potential for Jordan, "to the detriment" of Iraq)

APICORP using BP Statistical Review, USGS (2000) and Aguilera (adapted)

# Potential for E & D: Country Undiscovered and Expected Growth Volumes

- The resulting opportunities for E & D seem to be the greatest for Saudi Arabia and Iran, followed by Qatar, Iraq, the UAE, and Algeria.
- To a lesser extent, opportunities appear to be also present in Oman, Jordan, Libya, Yemen and Egypt.



# Conclusions

- Importance of MENA reserves but critical situation for half our sample
  - Algeria, Bahrain and Iraq likely to face a supply crunch
  - Oman, Syria and Tunisia spared by Dolphin/AGP/Transit pipelines
  - Critical supply pattern for UAE, Libya, Saudi Arabia and Kuwait
- MENA potential for reserve expansion higher than commonly assumed
  - Opportunities for E&D greatest for Saudi Arabia, then Iran
  - To some extent also for Qatar, Iraq, the UAE, and Algeria
  - Opportunities will be shifting towards unconventional gas
  - Therefore entailing considerably higher costs of F & D
- Raising domestic prices should be part of a more conducive climate for investment and re-investment

# A Post Scriptum: Thomas S. Ahlbrandt's email correspondence with the author

- "Basically concur[s]" with the analysis; offers some geological insights
- "U.S. source rocks are modest compared to the Silurian, Jurassic, Cretaceous and Tertiary source rocks in MENA. In particular, the Silurian is a huge unconventional Basin Center Gas Accumulations (BCGA) target in Algeria, Libya, Saudi Arabia, Iraq and Jordan."
- "South Pars and North Field are actually the conventional leg of a huge unconventional gas accumulation"
- "Unconventional resources are expensive to develop and require pretty sophisticated geoscientists and supporting technology (fracturing equipment, adequate horsepower and rig capacity) all of which takes time to build and deploy."

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