On Efficient Utilization of Egypt's Energy Resources: Oil and Natural Gas

Selim, Tarek

January 2007

On Efficient Utilization of Egypt's Energy Resources: Oil and Natural Gas

Tarek H. Selim
Faculty of Economics
The American University in Cairo

July 2006

ABSTRACT

The focus of this research is analysis and forecast for Egypt's energy resources of oil and natural gas. Running a risk of an oil shortage in the near term, Egypt's strategic energy resource should shift from oil to natural gas. Given an international energy market with high price variations for oil and more stable regional prices for natural gas, an efficient production schedule for Egypt's oil and gas resources based on domestic energy consumption and subsequent export/import forecasts has been derived. The methodology utilized is based on optimal resource extraction rates whereby dynamic efficient production schedules conditional on the constraint of sustainable growth rates in consumption (Hartwick's rule) dictate future energy requirements. Detailed strategies for Egypt's energy sector have been proposed, accompanied by their expected impact on the economy, with the following major guidelines: (1) policy shift from oil to gas as the strategic resource, (2) reduction/removal of oil subsidy, (3) adoption of renewable resource technology, and (4) future investment requirements.

1. INTRODUCTION:

Energy is a prime source of livelihood for many nations and is a cause of affluence for others. In Egypt, energy constitutes one fifth of the country's overall economic activity, a little less than half of the country's export revenues, and is a strategic resource for future growth. Yet, on the other hand, Egypt's energy reserves are quickly depletable, with a risk of over-consumption, production is aging as far as oil is concerned, and at the same time energy reserves are rather new when speaking about natural gas. Hence there exist future tradeoffs between oil and natural gas. Specifically, they should be considered as demand substitutes in addition to possessing future complementary roles in energy supply.

On the other hand, the strategic importance of the energy sector to the Egyptian economy is seen by observing other resources of comparative advantage in which the country is characterized: (1) cotton, (2) tourism, and (3) the Suez Canal. Export of cotton has been declining rapidly in the past couple of decades because of more effective world demand for substitutable products to Egyptian long-staple cotton fabrics. In addition, tourism as an industry is vulnerable to domestic and external shocks of the Middle East, and the Suez Canal is managed as a fixed income generator of government revenue. Thus, the leading strategic resource in which the Egyptian economy can depend on towards a path of sustainable development is that of energy.

Such a positive statement does not come without reservations. Notably, with the continuing decline in Egyptian crude oil production, Egypt’s hydrocarbon future lies in natural gas. In particular, the country’s gas reserves have increased so substantially over the last decade that it is now in a feasible position to start exporting large volumes of gas as well as catering for growth in domestic demand in the coming decade. Most recent estimates put Egypt's natural gas reserves ranked 14^{th} worldwide with 66 trillion cubic feet of proven reserves and up to 140 trillion cubic feet of probable reserves. However, the recent price hikes in crude oil determine an opportunity cost for the economy in terms of hard currency exports. A policy maker is then forced to think an answer to the important question: "What should Egypt do with its energy reserves?". Should the Egyptian economy export a sizeable trade of natural gas and leave oil for domestic consumption, even though such consumption is subsidized and creates a strain on the national budget? Or, on the other hand, should Egypt predominantly export its scarce resource, which is now oil, and leave domestic consumption to abundant natural gas reserves, even though there are switching costs involved? In either situation, there is an economic opportunity cost. The first situation creates a lost opportunity in terms of oil exports at high prices, coupled with domestic over-consumption at subsidized prices. The second situation creates an opportunity cost of natural gas exports and over-depletion of a strategic resource.

This research will tackle the topic of energy policy in Egypt on several fronts with an outline as follows:

- Analysis of the world energy market including reasonable estimates of future prices for oil and natural gas. The "most likely" scenario from the US DoE EIA's database will be utilized (US Department of Energy, Energy Information Administration Database, 2006).
- Analysis of the energy sector in Egypt including historical production, consumption, and net exports of energy resources.
- Derivation of a time path for Egypt's oil export/import schedule to meet future energy demand. In addition, the research will tackle when and to what extent will Egypt turn into a net importer of oil, and will analyze the trend of such behavior.
- Derivation of a time path for natural gas resource depletion, based upon proven reserves, and a forecasted timeline of natural gas consumption until 2025.
- Comparative analysis between oil and natural gas. This will include the calculation of price elasticity, income elasticity, and resource/GDP elasticity for both resources, and the calculation of the elasticity of substitution between oil and natural gas in consumption and production.
- The imposition of a sustainability constraint (Hartwick's rule) on resource extraction rates for oil and natural gas, with the objective of guaranteeing future

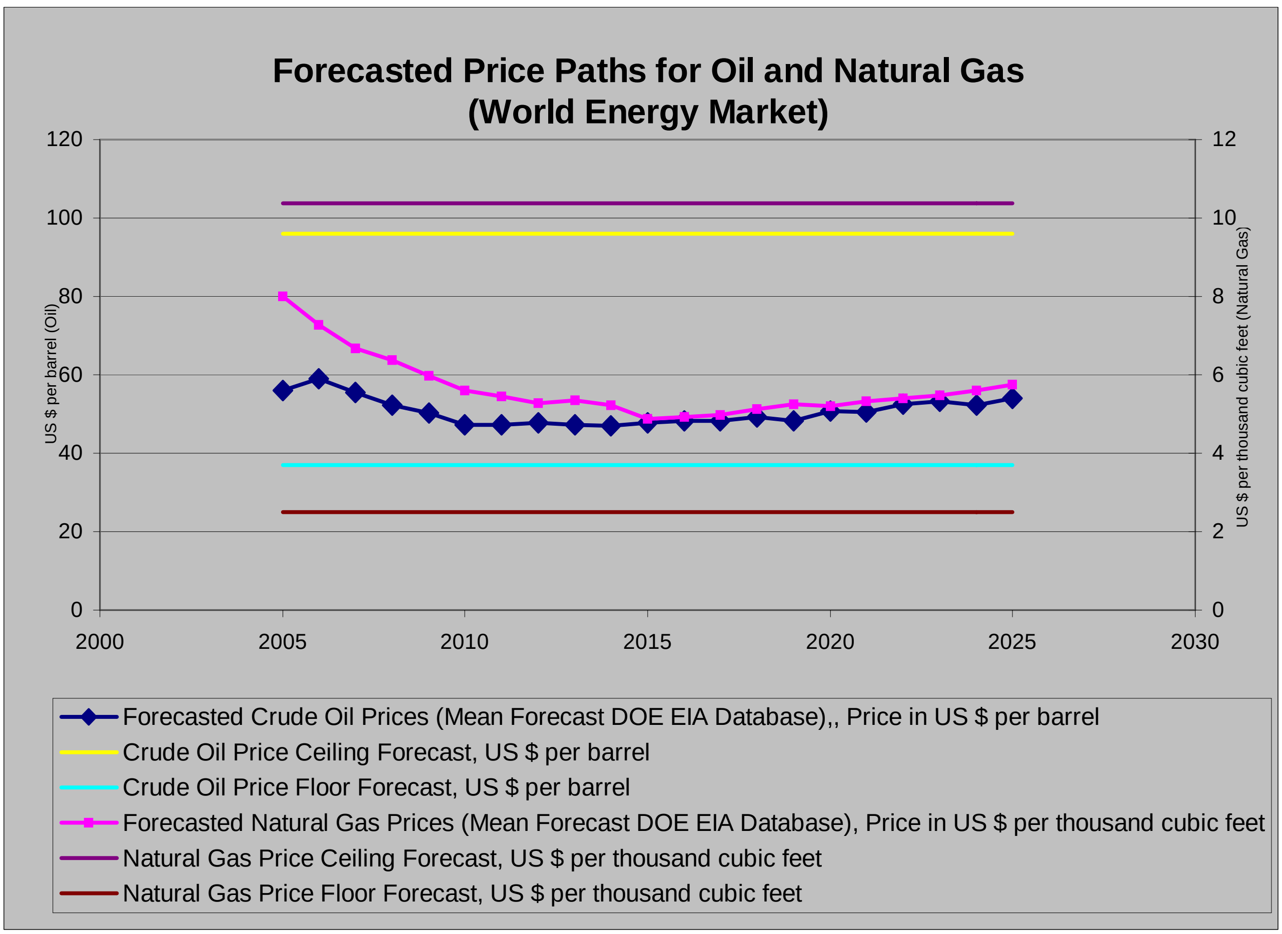
expected energy demand, conditional upon a GDP growth rate target of 6% per year.

- Derivation of an efficient export and production schedule for natural gas. This will be tackled in line with the derived export/import schedule for oil, and with the objective of meeting the above-stated sustainability constraint.
- Policy recommendations based on the above findings.

2. THE WORLD ENERGY MARKET:

Energy is considered a causal input to economic development, and the performance of the world energy market has a large effect on the quality of life of current and future generations. At the world energy market level, oil and natural gas have very different characteristics. The oil market contains a cartel (OPEC) and has a non-differentiated price element across geographic regions, whereas the natural gas market contains a price advantage within regions, less thermal efficiency, and cleaner emissions than oil. The main future energy challenges are to increase world energy security and to minimize the environment impact of energy use, especially carbon emissions. Although it is forecasted that world energy demand will increase, due to increasing demand by key developing countries like China and India, it is also expected that world energy supply will expand and overcome such demand. This scenario has been the main drive for forecasted future energy prices by the US Department of Energy, Energy Information Administration (World Energy Outlook) in its Energy Modelling System and Forecast Database 2006.

Although prices play a key role in the choice between alternative sources of energy, oil products are not easily displaced in certain types of use (mainly in transportation). Crude oil prices behave much as any other commodity with wide price swings in times of shortage or oversupply. Its prices are supply driven (mainly OPEC) more than demand. However, natural gas prices are predominantly demand-driven, and the fundamental drivers are weather, season, and storage inventory levels. Natural gas price varies widely between separate regional markets. The gas price tends to settle lower than the equivalent oil price, although there are circumstances, such as in East Asian markets, where delivered prices typically are higher than the oil equivalent. Comparing oil with gas reflects the fact that oil deposits tend to be in areas that are not major consumers of oil, but for natural gas the production and consumption regional match is much better. Therefore, there is hardly any world market for natural gas compared to oil. The effect of transportation costs is strongest in the case of natural gas, however crude oil is generally moved by pipeline because it is the cheapest mode. Oil's thermal efficiency is superior to gas as 1 cubic meter of oil has the same energy content as 1,000 cubic meters of natural gas, yet natural gas produces less carbon emissions than oil, and is therefore more environmentally friendly.

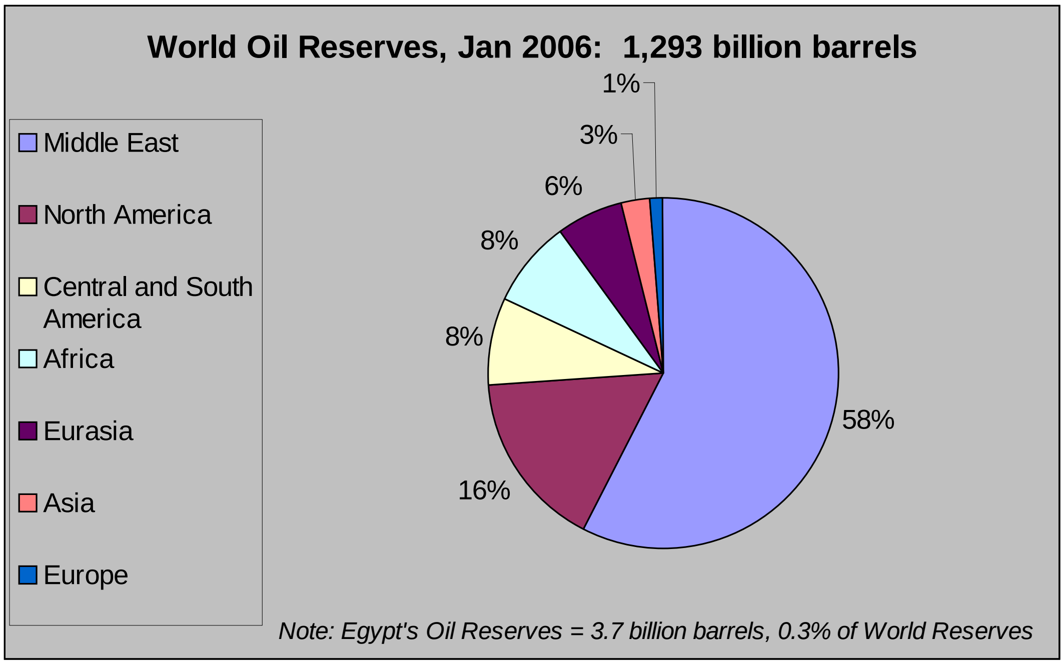


Most experts believe that there is no shortage of international oil and gas reserves over the next few decades, provided there is sufficient investment made in new production, transport and refinery capacity. Maintaining robust and transparent international markets for energy, including the free movement of capital, is a key policy objective. But many reserves lie in parts of the world where there is political instability, or there are other barriers to investment. This, however, is not considered to be a major impediment to energy supply so long as Middle East politics are contained and no new wars take place. Moreover, in terms of oil, non-OPEC production is expected to expand rapidly creating oversupply at future oil prices, and in terms of natural gas, gas reserves are expected to be excessively utilized (depleted) especially from areas in the former Soviet Union bloc.

World energy prices are expected to decrease with time until 2015, due to world supply expansion, expected reserve concessions, and lower growth in energy demand by China. However, analysts predict that oil prices will have large swings in the future, with an average price per barrel of $52 per barrel, having a price floor of $37 per barrel and a price ceiling as high as $96 per barrel in the future time period 2005-2025. Hence, oil prices are expected to have a large variance with time, but the average price is expected to be close to 2004 standards. The assumptions here is that political turbulence in Iraq will fade down with time, the nuclear crisis in Iran will be solved by indirect diplomatic means, and that energy prices will stabilize beyond the Bush administration in the United States. However, if the current problems in the Middle East intensify, particularly the threat of Iran halting its energy exports to the West, oil prices can strike as high as $96 per barrel. The issue with natural gas is somehow different. Russia and Ukraine, in addition to Qatar and Iran, hold the largest natural gas reserves, with Russian reserves estimated at more than 1,400 tcf at a bare minimum. These world reserves are predominantly unutilised creating relative resource abundance at low effective prices. Hence, even though natural gas has lower thermal efficiency compared to oil, its expected future price is stable. More precisely, the average price for natural gas per thousand cubic feet, for the time period 2005-2025, is $5.67. The lowest estimate is at $4.87 and the highest at $6.66. Hence, price variation for natural gas is 15%. This runs in contrast to future expectations of oil prices, with upper price variation reaching 80% and a lower price variation of 27%.

On the consumption side, worldwide energy demand is expected to rise over the next 25 years. Total world consumption of energy is expected to expand by 54 percent, from 404 quadrillion British thermal units (Btu) to 623 quadrillion Btu in 2025. Developing nations of the world are largely expected to account for the increment in world energy consumption. Energy demand in the emerging economies of Asia, which include China and India, is expected to more than double in the next quarter century. Primary energy needs, for developing countries, is expected to grow annually at a growth rate of 2.7 percent until 2025. In contrast, in the industrialized world, with its more energy consuming nations, energy use is expected to grow at a much slower rate of 1.2 percent per year over the same period. Natural gas is expected to be the fastest growing primary energy source worldwide, maintaining average growth of 2.2 percent until 2025. In comparison, 1.9 percent average annual growth rates are projected for oil and for renewable resources, 1.6 percent annual growth is expected for coal, and 0.6 percent annual growth is projected for nuclear power (on a Btu basis). Yet, on the other hand, the persistence of oil is evident since oil is expected to remain the dominant energy fuel for the next 25 years, with its share of total world energy consumption remaining in the 40% range through 2025. However, oil fuel is expected to decline regarding electricity generation, with other fuels (especially natural gas) providing a more favourable alternative to oil-fired generation.

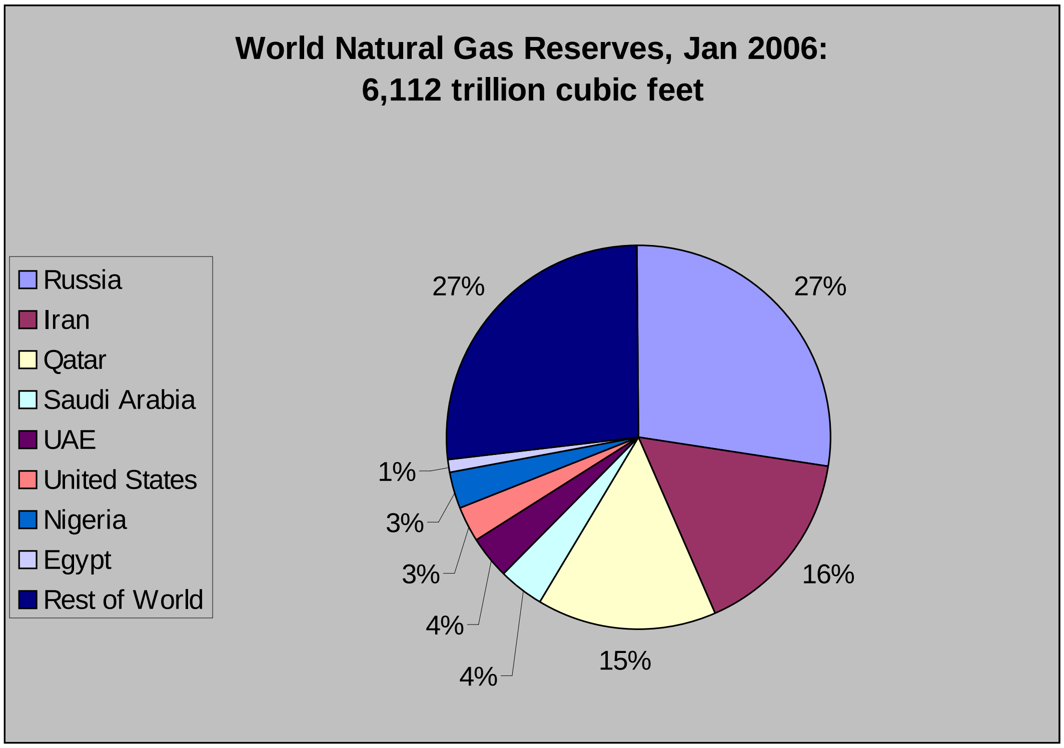
On the production side, OPEC is expected to be the dominant supplier of oil in the international market in the medium term, and its production choices will significantly affect world oil prices. The expected rise in world oil consumption, ranging from a low of 36 million barrels per day to 56 million barrels per day in the next twenty years, will be met by world oil supply. There is wide agreement that resources are not a key constraint on world demand to 2025. Rather more important are the political, economic, and environmental circumstances that could shape developments in oil supply and demand. World oil supply is expected to increase by about 40 million barrels per day relative to current levels. Increases in production are expected for both OPEC and non-OPEC producers, however, only 40 percent of the total increase is expected to come from non-OPEC areas, due to higher costs of capacity expansion. Over the past two decades, the growth in non-OPEC oil supply has resulted in an OPEC market share substantially under its historic high of 52 percent in 1973. New exploration and production technologies, in addition to process innovation leading to cost-reduction programs, will contribute to the outlook for continued growth in non-OPEC production.



Source: "Worldwide Look at Reserves and Production", Oil and Gas Journal, Vol. 103, December 2005

On the other hand, OPEC production is estimated to increase by 25 million barrels per day relative to current levels. It is generally acknowledged that OPEC members with large reserves and relatively low costs for expanding production capacity can accommodate sizable increases in petroleum demand. OPEC capacity utilization is expected to increase sharply reaching 90 percent in 2015 and remaining stable through 2025. In addition, with Persian Gulf producers enjoying a reserve-to-production ratio that exceeds 115 years, substantial capacity expansion clearly is feasible. Natural gas production is also expected to increase substantially in the next twenty years even though gas has been historically viewed as a lower value commodity. Future energy supply, however, will be greatly affected by the depletion of natural gas reserves in countries like Russia, Ukraine, United States, Qatar, and Iran. In the developing world, gas production is expected to exceed consumption by 16 trillion cubic feet by 2025, and in the former

Soviet Union bloc alone, production is projected to exceed consumption by 11.7 trillion cubic feet. As a result, Russia and other Eastern European (former Soviet Union) countries are expected to be the major source of exports of natural gas to the rest of the world.



Source: "Worldwide Look at Reserves and Production", Oil and Gas Journal, Vol. 103, December 2005

An important element of comparison between oil and natural gas in the international energy market is price. Oil prices behave with wide price swings in times of shortage or oversupply, but those price swings are expected to be short in duration (peak or trough phases) in the future time period until 2025. Even though oil prices are predominantly supply-driven, natural gas prices, in contrast, are predominantly demand-driven and are also differentiated by geographic region due to pipeline transportation costs. In addition, the expected profit margin for oil through 2025 is 70% on average, since the cost of oil production is expected to decrease due to process innovation reaching as low as $3-$7 per barrel (the lower end attributed to Persian Gulf producers). In contrast, the expected profit margin for natural gas through 2025 is about 20%, which makes economies of scale in natural gas production more important than oil. This runs in line with substantial increases in natural gas production in the future.

Comparative Table: World Energy Market for Oil and Natural Gas: Projections until 2025

	World Oil Market	*International Natural Gas Market*
Pricing	Large price swings until 2025: $37 price floor, $96 price ceiling, $57 mean price (US $ per barrel). High end price variation at 80%, lower end price variation at 27%.	Stable prices at $5.7 with $0.8 as standard deviation through 2025 (US $ per thousand cubic feet). Maximum price swings (variation) at 15% both sides.
Profit margins	There is a uniform world oil price (non-differentiated on a regional level), and profit margin is expected at 70% due to cost-reducing process innovations, with least cost estimate at $3 per barrel (Persian Gulf producers).	Differentiated prices by region, with profit margins expected at 20% requiring economies of scale.
Consumption	1.9% annual growth rate to 2025. Consumption end use predominantly in transportation with declining power generation demand for oil.	2.2% annual growth rate to 2025. Consumption end use in residential, commercial and power generation.
Reserves	1,293 billion barrels (Jan 2006). Modest expectations of additional reserves.	6,112 trillion cubic feet (Jan 2006). High expectations of probable reserves.
Production	OPEC remaining a key player with declining dominance. Production capacity reaching maturity in 2015 and remaining stable to 2025. Reserves to production ratio of 115 years (Persian Gulf region)	No OPEC (cartel) equivalent expected. Net production surplus of 16 trillion cubic feet by 2025 in developing countries.
Thermal efficiency	Oil is more thermal efficient than gas. 1 cubic meter of oil has the same energy content as 1,000 cubic meters of natural gas	Gas is less thermal efficient but is a cleaner fuel.
Kyoto Protocol	Kyoto Protocol carbon emissions reduction standards will affect oil market negatively more than gas.	Kyoto Protocol standards will lead to expansion of natural gas market.
Political risk	Oil has more political risk (Middle East dominance).	Lower political risk of natural gas (Eastern Europe / Eurasia dominance)
Elasticities	Oil is more price inelastic than natural gas, but carries higher income elasticity.	Natural gas has lower income elasticity, but is more price elastic than oil.
Transportation cost	Alternatives to oil pipeline transportation exists, but pipeline is expected to remain the cheapest way.	There is no expected alternative to pipeline for natural gas transportation except LNG.

3. EGYPT'S ENERGY SECTOR:

The oil and gas sector is considered to be one of the most important and strategic sectors in the Egyptian economy. The Egyptian government gives the sector high priority and has outlined the following strategic objectives for its enhancement (Ministry of Petroleum):[1] (1) increase Egypt's crude oil and natural gas reserves by encouraging onshore and offshore exploration, (2) better scientific management of crude oil and natural gas reserves and production, (3) protect Egypt's environment and ecological systems, (4) support and encourage the involvement of the Egyptian private business in the Petroleum sector.

Energy sector in Egypt is mainly supervised by the Organization for Energy Planning (OEP) as it is responsible for planning, analyzing energy policies, examining energy resources and collecting data. The Egyptian government is the main player in the energy sector represented in the Egyptian General Petroleum Company (EGPC) and the Natural Gas Holding Company (EGAS). However, the private sector is rising through several joint-ventures between the government and foreign companies to explore and develop the country's energy resources for both oil and gas.

In 2003, the production of petroleum constituted around 8% of GDP, which was the largest single industrial activity. During the first part of 2005 the export of crude oil and petroleum products constituted 40% of Egypt's export returns and around 20% of its GDP.[2] By the start of 2006, Egypt's proven oil reserves have been maintained officially at 3.7 billion barrels with no substantial increase in the past decade. However, export of oil is rapidly declining and Egypt is seen to be a net importer of oil in the short run. Natural gas, on the other hand, is abundant at 66 trillion cubic feet, but is less thermally efficient and has large overhead costs in transporting its energy content across nations.

---

[1] Ministry of Petroleum official website http://www.emp.gov.eg/ENGLISH/objectives.html

[2] U.S. Department of Energy, Energy Information Administration, *Country Analysis briefs: Egypt*, May 2005: www.eia.gov/emeu/cabs/egypenv.html.

Egypt experienced promising growth rates in the 1990s. Unfortunately such a growth trend did not continue with the turn of the 21st Century and Egypt's economy witnessed declining growth rates in 2001 and 2002. However, in 2004 the Egyptian economy started on a slow road to recovery with GDP growing at 4.5% in 2005 and 3.6% in 2004 as compared to 2.9% in 2003.[3]

Egypt's production of crude oil during 2004 was around 594,000 barrels per day (bpd), lower than the 2003 production level of 618,000 bpd (a decrease of 3.9%), yet a far cry from 1996 peak of 922,000 bpd. The majority of the current fields have reached their maturity and have begun their downward operational decline. The government is trying to overcome this maturity problem by increased investments to enhance the production of oil, increased exploration activity in the hope of discovering new fields while at the same time carefully curbing consumption through the slow withdrawal of subsidies and the encouragement of the use of compressed natural gas (CNG) as an alternative fuel.[4]

Egypt has been a net exporter of crude oil and petroleum products, however due to increased domestic consumption net exports have considerably declined over recent years. The substantial increases in world oil prices which have reached more than $ 70/b, have made up for this decline, with oil revenues actually witnessing an increase. With respect to liquefied natural gas (LNG), Egypt started to export in early 2005 and hopes to increase such exports even further with the expected expansion of capacity due to materialize by end of 2006.[5]

Egypt's golden years, in terms of net export earnings were in the mid 1990s. Production then declined sharply indicating field maturity, with the problem being accentuated by a steady rise in domestic consumption, and with such an accentuation having a multiplier effect on energy demand due to over-consumption at subsidized prices.

---

[3] International Energy Outlook, U.S. Energy Information Administration, October 2005, www.eia.doe.gov/emeu/cabs/carbonemiss/chapter5.html.
[4] "*The Petroleum Industry in Egypt: Investment & Prospects*", American Chamber of Commerce in Egypt (Am Cham), Business Studies Series, December 2003.
[5] Ibid.

Net oil exports steadily increased over the last 25 years, because the rate of growth of oil production exceeded the rate of growth in oil consumption. Although domestic consumption has levelled off in recent years, it is expected that in the short run, Egypt would become a net importer of oil. Hence Egypt is deprived of possible foreign currency earnings as consumption erodes any possible exports and swallows the already declining production rates. Furthermore, Egypt will also probably have to draw on its foreign currency reserves, or increase its domestic indebtedness to maintain a system that is over-ridden by heavily-subsidized domestic oil and gas products. Oil and gas subsidies are rife in both the consumer as well as the intermediate sectors and are thus intertwined in all the productive activities in the economy.[6] Egypt is trapped with a tradeoff between exporting crude oil and exporting refined oil products. If it wants to maintain being a crude oil exporter then it would have to decrease the throughput to refineries and hence decrease its refined oil export revenues**.** The significance of the petrochemicals industry is further accentuated by the fact that natural gas is one of its primary inputs. Therefore, Egypt's natural gas reserves provide an excellent potential advantage for the production of petrochemicals. Unfortunately, production of petrochemical products only covers a third of domestic demand. This should encourage the government to enhance this sector in a bid to improve its deficit situation. Furthermore, petrochemicals are strategic intermediate products to many industries, and strengthening that sector would strengthen Egypt's industrial base and ensure a sustained raw material supply chain.[7] The Egyptian government undertook a long term investment plan incorporating around $10 billion in order to develop the petrochemical industry by the year 2021. The plan is envisaged to take full advantage of Egypt's gas reserves to maximize value added benefits. A by-product of this ambitious plan is the import substitution of the current $3 billion bill that Egypt foots to cover petrochemical imports.[8]

---

[6] *"Apache Egypt's Contribution to the Egyptian National Economy"*, Rodrigo Seda., The American University in Cairo, 2005, p. 27-28.
[7] Am Cham, Ibid, p.34.
[8] Middle East Economic Digest, Egypt: Petrochemicals, January 2003.

The natural gas sector is one of the fastest growing sectors in the Egyptian economy and production increased more than two-fold between 1999 and 2003[9] and almost 1000-fold over the last 20 years by 2005 standards. Egypt's future energy outlook therefore seems to be more and more affiliated with natural gas, which is currently Egypt's main source of energy reserve. It is worth mentioning that the substantial increase in the production of natural gas liquids helped to iron out some of the negative repercussions of the reduction of crude oil production. The average daily production of natural gas during 2004 was 3.6 billion cubic feet per day (bcf/d).[10] Egypt's proven natural gas reserves are estimated to be 66 trillion cubic feet (tcf), with actual reserves probably amounting to more than double that volume. Total gas consumption took off when thermal power plants were ordered to convert from oil to gas. This was a pivotal and strategic decision made in Egypt's energy policy history. These now constitute around 65% of total gas consumption.[11] In 2001/2002, Egypt ranked third in worldwide natural gas consumption, with a daily consumption of 2.6 billion cubic feet (bcf).[12] Around 84% of Egypt's electric generating capacity is thermal (natural gas), with the remaining 16% hydroelectric from the Aswan High Dam. The government has converted all oil-fired plants to run on natural gas as their primary fuel.[13] With the expected growth in electricity demand in Egypt, the implications on the increased domestic demand of natural gas cannot be overlooked. Again, the question of pricing and subsidization comes into focus and should be addressed.

In 2001, Egypt agreed with Jordan and Syria to extend its Sinai natural gas pipeline into Jordan. In 2003, the Egypt-Jordan gas pipeline at Taba was launched, and Egypt commenced export of natural gas. There are future plans to link this pipeline to Syria, Lebanon, Turkey and Cyprus.[14] Egypt also has an initial agreement for the establishment of an oil and natural gas pipeline to Libya.

---

[9] Ibid.
[10] Ibid.
[11] U.S. EIA, Ibid.
[12] World Energy Council, Energy in Egypt 2002: www.worldenergy.org/wec-geis/wec-info/structure-organisation/ea/cairo/stats/eie.asp.
[13] Ibid.
[14] U.S. EIA, Ibid.

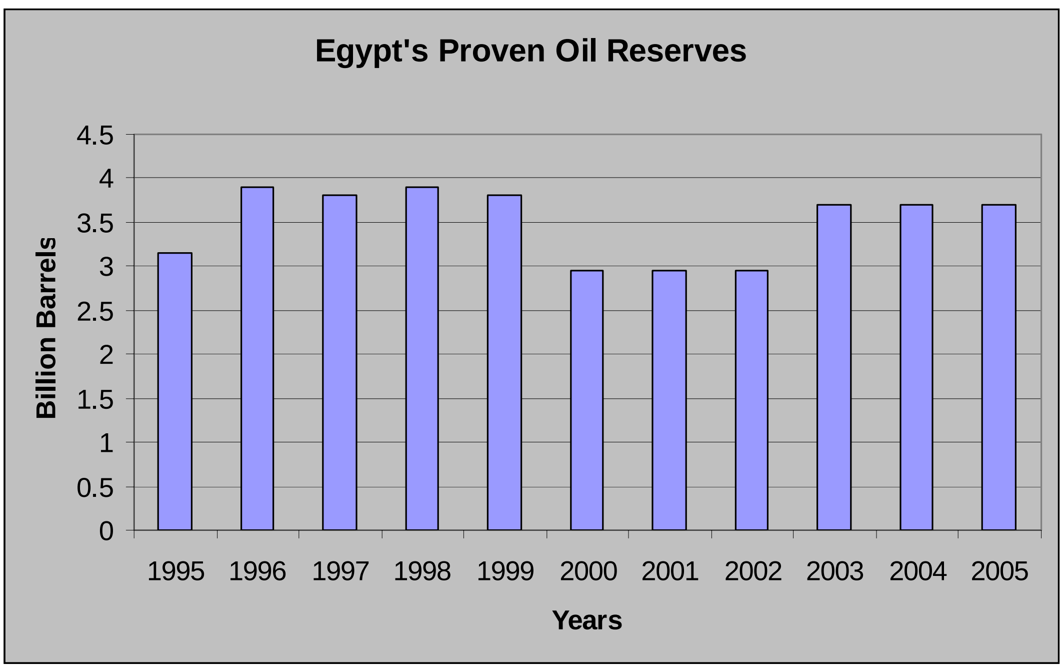
SWOT Analysis for Egypt's Energy Sector

STRENGTHS	**WEAKNESSES**
• Substantial natural gas reserves (66 tcf) • Existing joint ventures with long term interests in Egypt • Government encouragement of private and foreign investments • Conversion (from oil to gas) of most electric power plants and public transportation • Sumed pipeline from Ain Sukhna to Mediterranean • Export pipeline to Jordan.	• Maturity of oil fields (X-inefficiency) • High domestic consumption due to subsidisation (overconsumption as an opportunity cost to exports) • High capital intensive industry which cannot solve the unemployment problem in Egypt • Egypt not yet established as a natural gas exporter.
OPPORTUNITIES	**THREATS**
• New oil and gas discoveries (analysts put a ceiling estimate of 8 billion barrels of probable oil reserves and 180 trillion cubic feet of probable gas reserves) • Competitive advantage in the Egyptian petrochemical industry • New joint ventures (change in government policy) • Foreign direct investments and technology transfer (limited applicability) • Potential gas export to Syria, Lebanon and Turkey • Long term future gas export to Europe (limited potential due to competition from Russia, Ukraine, and Iran).	• Middle East political instability and threat of war in the region • Oil shortage: high domestic demand will swallow all production and Egypt will become net oil importer in the short term • A decline in Egypt's foreign currency balances due to expected oil imports • Drying up of oil fields • Substantial and uncontrollable increase in public debt due to energy subsidies • Excessive strain on long term economic development by a large balance of trade deficit by 2015.

4. THE OIL MARKET IN EGYPT:

Reserves

The petroleum industry plays a key role in the Egyptian economy. The export of petroleum products accounts for about 40% of Egypt's export revenues, and about 20% of Egypt's GDP. Egypt's proven oil reserves were estimated at 3.6 billion barrels on average from 1996 to 1999, but in January 2000, the government released a revised estimate of probable crude oil reserves, raising the figure to 8.2 billion barrels, based on new finds and increased recovery ratios. Even though the proven crude oil reserves declined and stood at 2.9 billion barrels from 2000 till 2002 (AmCham, 2003, p.12), as of 1 January 2006, Egypt's proven crude oil reserves were estimated at the prevalent amount of 3.7 billion barrels (APRC, 2003, p.94). The figure below shows Egypt's proven oil reserves from the year 1995 till 2005.

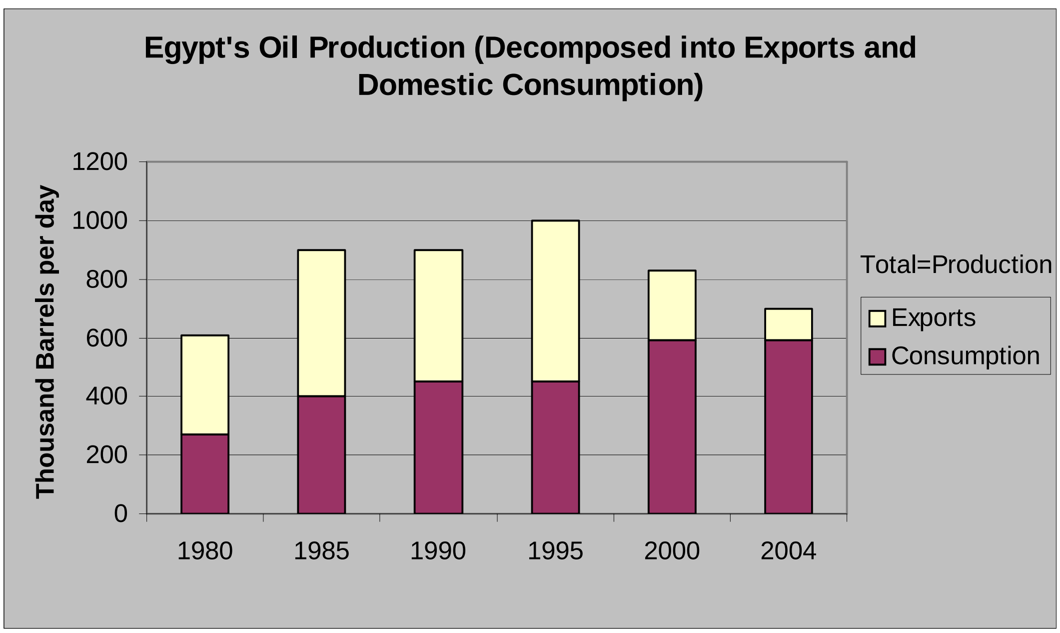


Source: Energy Information Administration (2006)

Production and Consumption

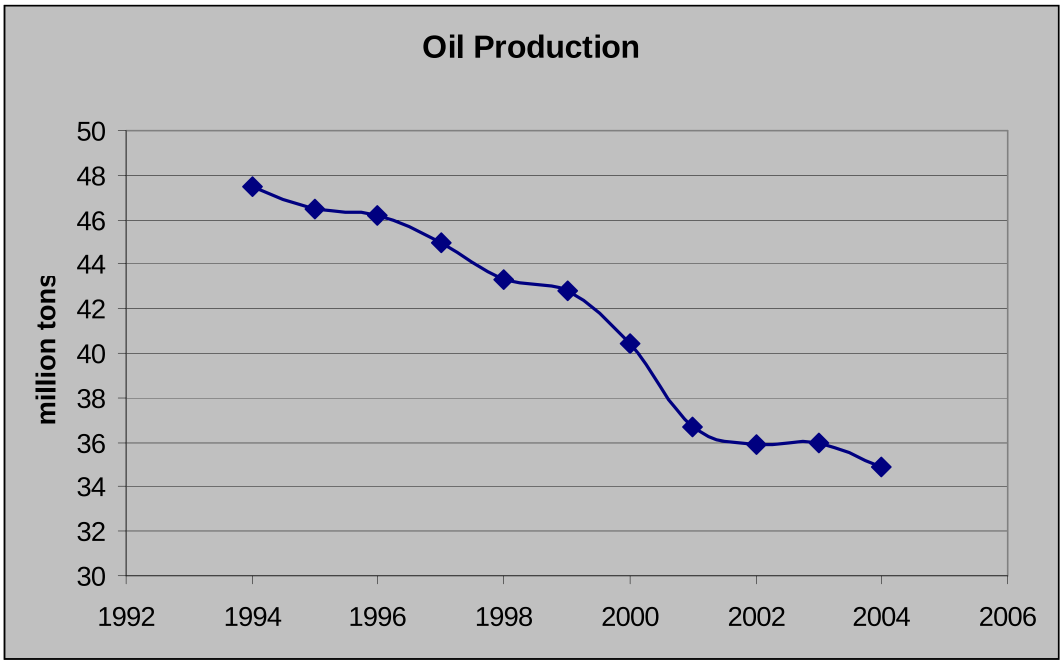
Egyptian oil production in 2003 averaged 618,000 barrels per day (b/d), down sharply from a peak in 1996 of 922,000 b/d, but only modestly below the 631,000 b/d in 2002 (AmCham, 2003, p12; EIA). In contrast, domestic demand for oil has been climbing from

501,000 b/d in 1996 to 585,000 b/d in 1999 due to rapid economic growth between 1995 and 1998. Then it reaches its peak in 2003 at 566,000 b/d. The sharp increase in local oil consumption over the past decade can be attributed to two factors: economic growth in the late 1990s contributed to higher oil needs and government subsidies as most oil products are subsidized by the government to prevent rising prices. The prices of most types of fuel have not changed for the past decade, which has encouraged over-consumption (AmCham, 2003, p.19). Increased exploration, particularly in new areas, may lead to hope to find enough new discoveries to enable production above the 800,000 b/d level. The below figure shows the trend of production, consumption and export of oil in Egypt from 1980 till 2004. Decomposing the country's total production into domestic consumption and export trade, it is seen that by 2004/2005, the country has squeezed its export revenues by over-consumption.



Therefore, despite the buoyant level of exportation activity and the large number of discoveries made each year, which are brought into production as rapidly as possible, there seems little prospect of Egypt reversing the decline in its crude oil output in the future. Not only is oil production steadily decreasing, but domestic oil consumption continues to rise, putting a double squeeze on the amount of oil available for export.

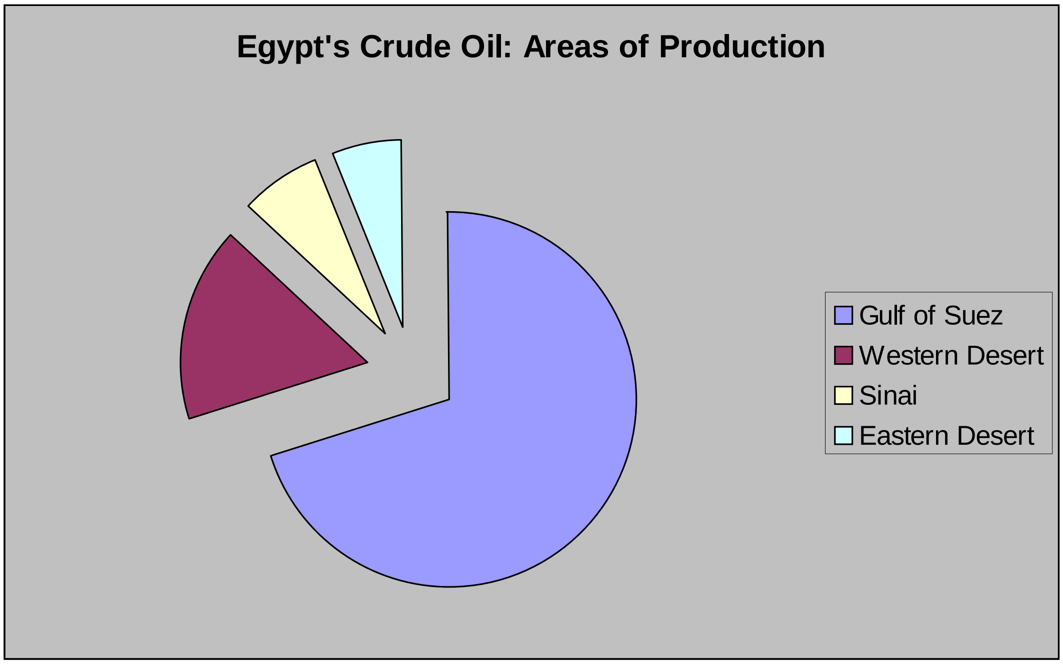
Some analysts suggest that Egypt could cease to be a net oil exporter sometime between 2007 and 2010 (APRC, 2003, p.94). As will be analyzed later, the author believes that net imports of oil will become a factual reality very soon, if not by the end of the current year.



Source: Information and Decision Support Center, Government of Egypt

Areas of Production

The Gulf of Suez remains by far the biggest producing region in Egypt, accounting for about 70% of total oil production, although its share is falling. The second biggest oil-producing region is the Western Desert, which accounts 17%. Egypt also draws oil from the Sinai Peninsula (7%) and the Eastern Desert (6%) as shown in the following figure (APRC, 2003, p.94; OFE, 2001).



Oil Market Suppliers and Concessions

The state-run Egyptian General Petroleum Company (EGPC) controls the petroleum industry and is the only company authorized to import and export crude oil and petroleum products. EGPC is active in the upstream, downstream, and petrochemical sectors.

Oil in the Gulf of Suez is produced mainly by Gupco (Gulf of Suez Petroleum Company), a joint venture between BP-Amoco and EGPC. The fields in this region are mature; having been in operation since the 1960s and 1970s, and as such have been seeing declining levels of production. Still, this area remains a significant source of Egypt's production; contributing around 360,000 b/d. Gupco is trying to extend the operating life of the fields through investments in production efficiency and greater exploration. BP-Amoco has announced plans to invest $450 million over the next six years to improve technology. Petrobel, Egypt's second largest oil producer is also planning technology improvements to extend the life of the Belyim fields near the Gulf of Suez. Petrobel is a joint venture between EGPC and Italy's ENI-Agip. Other major companies in the Egyptian oil industry include the Badr el-Din Petroleum Company (BAPECTO) (a joint venture between EGPC and Shell); Suez Oil Company (SUCO) (a joint venture between EGPC and Deminex); and El Zaafarana Oil Company (EGPC and British Gas), and Shell.

Overall, petroleum production has not declined in Egypt as sharply as in the Gulf of Suez, due to new discoveries in the Western Desert and Upper Egypt. Production levels at the Qarun Block in the Western Desert, operated by independent producers Apache and SeaGull Energy, surpassed 60,000 b/d in mid-2000. Development of new fields in the Qattara Depression and El Alamein are expected to add 40,000 b/d in new production as they come online. In October 1997, Apache and SeaGull announced a major discovery estimated to contain around 100 million barrels of crude oil in the Western Desert at the East Beni Suef Concession. Other recent discoveries in the Western Desert include one south of Daba near Alexandria, another at the Qarun Concession near Cairo, and one in the Meliha Concession near Mersa Matrouh.

Egypt is conducting offshore exploration in the Mediterranean Sea. In February 1999, Shell won the rights to the largest concession yet in deep water off Egypt's Mediterranean coast. BP-Amoco and Elf Aquitaine and ENI-Agip have also won concessions. It is believed large oil reserves may lie off the coast of the Nile Delta, while Shell has high hopes for its North East Mediterranean Deepwater Concession.

In the first quarter of 2001, Egypt placed 32 exploration areas on the auction block for international bidding, including virgin deepwater territory in Egypt's western Mediterranean close to the Libyan border. Acreage in the gas-rich Nile Delta, Gulf of Suez, and Western Desert are also available. Bids are due to EGPC's Geological & Geophysical Center in Nasr City by November 15, 2001. The 2001 auction follows a failed 1999 bid round when commercial negotiations for 15 blocks resulted in no significant activity. Egypt decided to subdivide the 15 exploration blocks into smaller, more manageable blocks in hopes that more companies will have incentive to invest in Egyptian territory. Increases in world oil prices, and recent international tenders by Algeria and Libya likely will raise more interest in this recent round of bidding (OFE, 2001).

Suez Canal & Sumed Pipeline

Egypt has strategic importance because of its operation of the Suez Canal and Sumed (Suez-Mediterranean) Pipeline, two routes for export of Arabian Gulf oil. The SCA (Suez Canal Authority) offers a 35 percent discount to liquefied natural gas (LNG) tankers, with even deeper discounts for the largest LNG tankers, as well as other discounts for oil tankers (AmCham, 2003, p.14; OFE, 2001)

The SCA is continuing enhancement and enlargement projects on the canal. The canal has been deepened so that it can accept the world's largest bulk carriers, but it will need to be deepened further to 68 or 70 feet, from the current 58 feet, to accommodate fully laden very large crude carriers (VLCCs). The SCA has attempted to reach an agreement with its main competition for northbound crude traffic, the Sumed pipeline. Such an agreement could bar any tanker small enough to traverse the canal from transporting oil through the pipeline. The SCA offers incentives for tankers to off-load a portion of its cargo through the Sumed, allowing for passage through the canal, and reloading at the other end of the pipeline (AmCham, 2003, p.14; OFE, 2001).

The Sumed pipeline is an alternative to the Suez Canal for transporting oil from the Arabian Gulf region to the Mediterranean. The 200-mile pipeline runs from Ain Sukhna on the Gulf of Suez to Sidi Kerir on the Mediterranean. The Sumed's original capacity was 1.6 million b/d, but with completion of additional pumping stations, capacity has increased to 2.5 million b/d. The pipeline is owned by the Arab Petroleum Pipeline Company (APP), a joint venture between Egypt (50 percent), Saudi Arabia (15 percent), Kuwait (15 percent), the U.A.E. (15 percent), and Qatar (5 percent). The APP also has been increasing storage capacity at the Ain Sukhna and Sidi Kerir terminals (OFE, 2001).

Refining

Egypt has nine refineries with a combined crude oil capacity in excess of 727,000 b/d, and is Africa's second leading refining center (following South Africa). One of the largest refinery is El-Nasr refinery at Suez with a total capacity of 146,300 b/d. The Egyptian government controls all refinery operations in Egypt through its state-owned subsidiaries.

The El Mex and Amerya refineries in Alexandria are operated by the Alexandria Petroleum Company. There are two refineries at the port of Suez; the El Suez Refinery Company manages one of them, while the El Nasr Refining Company operates the other. The Mostorod Refinery and the Tanta Refinery are both near Cairo and are operated by the Cairo Oil Refining Company. The largest refinery in Egypt is the Mostorod complex near Cairo with a capacity of almost 157,000 b/d. The Assyout Petroleum Company operates the Assyout Refinery, south of Cairo, and the El Nasr Refining Company operates the Wadi Feiran Refinery on the Sinai Peninsula.

The Egyptian government announced a $2.5 billion spending package to build five additional refineries and petrochemical plants. Included in this plan is construction of a 35,000 b/d, $450 million hydrocracker at the El Nasr Petroleum Company refinery in Suez. This will package will also boost the refining capacity at the Asyut refinery to about 100,000 b/d.

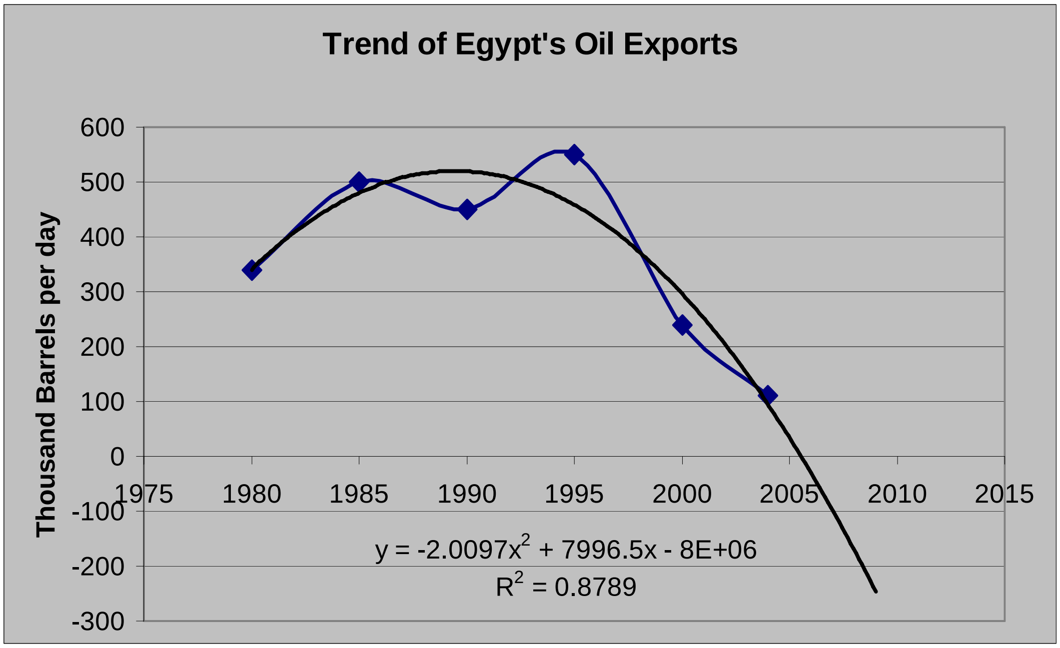
In July 1997, the Egyptian government awarded a contract to an Egyptian-Israeli private sector joint venture for construction of the 100,000 b/d MIDOR refinery at Sidi Kerir, near Alexandria. The refinery started trial production in April 2001, and includes a 33,400 b/d hydrocracker and a 22,800 b/d coker. Initially the refinery was set up to take Gulf crudes from the Mediterranean terminal of the Sumed pipeline to sell product to Israeli and other Mediterranean markets. Arab countries, however, have been refusing to supply petroleum due to Israel's interest in the refinery, which caused the refinery to run on Egyptian crudes supplied by EGPC. In May 2001, Israel’s privately-held Merhav MNF Ltd. sold its 20% stake in MIDOR to the National Bank of Egypt (NBE), putting the refinery entirely in the hands of the Egyptian government (OFE, 2001).

Exports

Egypt has little crude oil available for export, since its domestic refining industry requires nearly 700,000 b/d of feedstock whereas oil production fell to 618,000 b/d in 2004. EGPC is still able to export a small volume of crude, but its exports of refined products are now greater in volume as well as in value. Taking account of domestic oil consumption of some 566,000 b/d, the country was a net exporter of around 100,000 b/d of oil in 2004 (AmCham, 2003, p.19; EIA). However, net exports surplus sharply decreased since 1995 from 560,000 b/d as shown in next figure. Most recent estimates for 2004/2005 put Egypt's oil production, consumption, and exports at 700,000 b/d, 590,000 b/d and 110,000 b/d respectively.

The trend of Egypt's oil exports is seen in the following figure. The author uses a combination of moving averages and non-linear forecast to estimate expected future trend of oil exports using historical data ($R^2 = 87.89\%$). The main assumption has been a constant demand income elasticity based on historical averages (1980-2005), a constant population growth rate and a targeted increase in average income (GDP per capita) of 6% annually. This scenario is seen as the most reasonable with current information[15]. Conditional on those assumptions, the author estimates that Egypt will become a net importer of oil by the beginning of 2007, and that oil demand will exceed domestic supply reaching required oil imports equivalent to 100,000 b/d by 2008, 300,000 b/d by 2015, and almost 600,000 b/d by 2025.

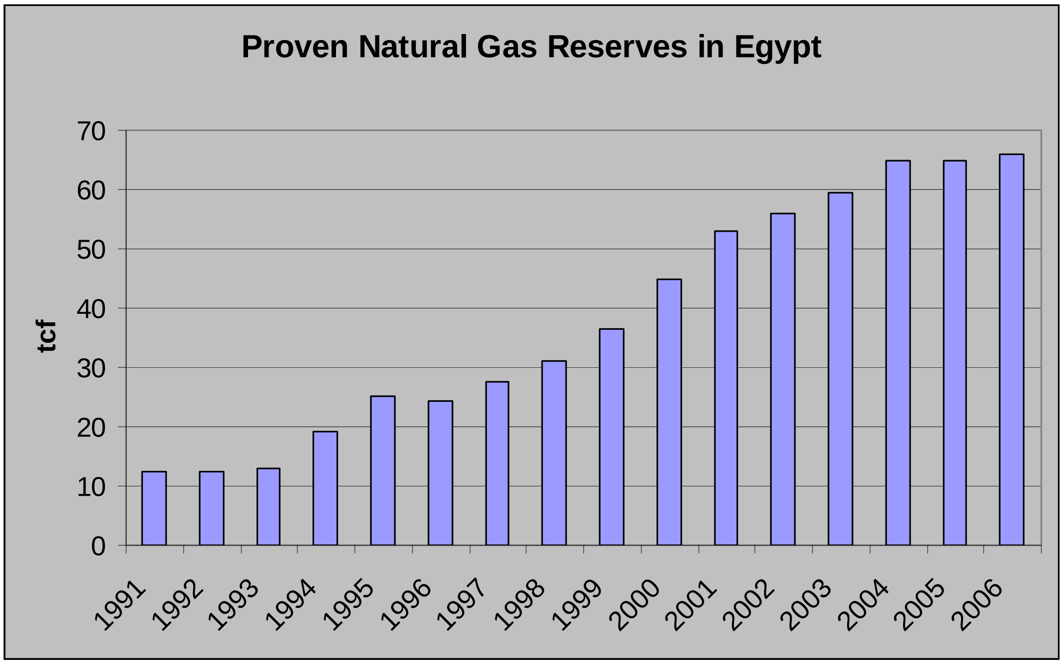
[15] Income elasticity of demand is calculated to be the prime determinant of effective quantity demanded for oil at a historical GDP/demand elasticity of 0.3, such that future oil exports is the residual of production, after accounting for needed domestic consumption per capita. This is re-enforced by a completely inelastic price elasticity of oil demand at 0.02. Hence, the core assumption here is that quantity demanded is a main function of population and future income levels but not predominantly based on future prices.



5. NATURAL GAS IN EGYPT:

Reserves and Main Areas

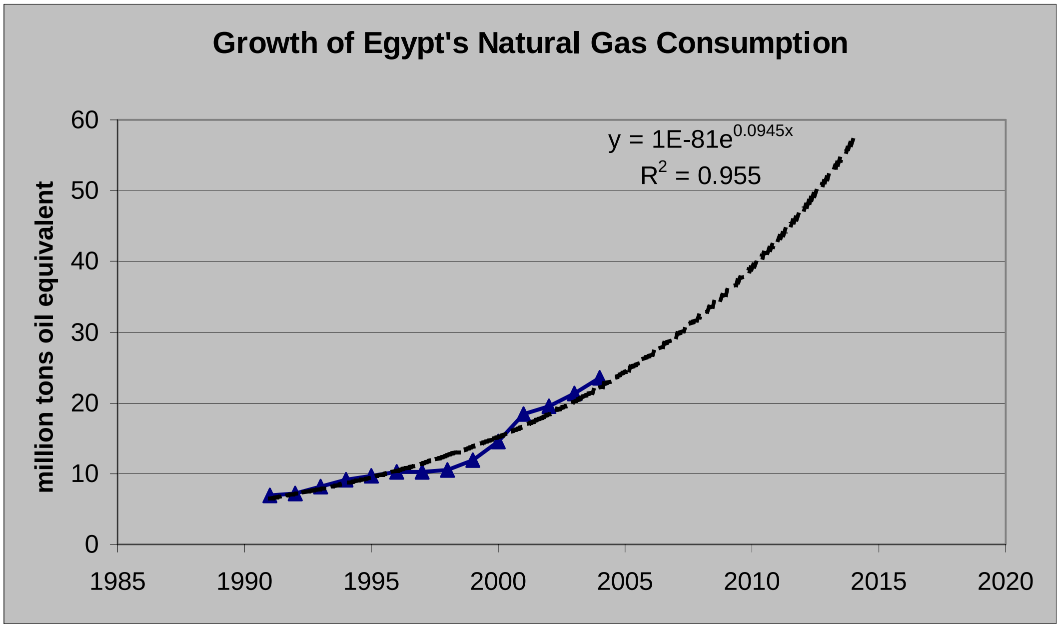
Natural gas is destined to become more and more important to the energy future of Egypt because of major recent discoveries making it an abundant resource. There are vast reserves of natural gas with a strong potential for more discoveries. Beginning in the early 1990s, foreign oil companies began more attractive exploration for natural gas in Egypt, and very quickly found a series of significant natural gas deposits especially in the Western Desert, the Nile Delta, and under the Mediterranean Sea. Proven reserves stand at 66 trillion cubic feet (tcf) in 2006, a little more than the 65 tcf in 2004, up from 55 tcf in 2002, and significantly up from 40 tcf in 2000, with probable reserves estimated at 120-140 tcf as a lower bound estimate. Major discoveries between 1997 and 2001 in the Nile Delta and the Western Desert have doubled Egypt's proven reserves. Next figure shows the increase in Egypt's natural gas as proven reserves.



Studies carried out by international companies indicated that there were some 80-117 tcf of gas reserves remaining to be discovered: 65-84 tcf in the Mediterranean and Nile delta regions and 15-33 tcf in the Western Desert (APRC, 2003, p.102).

Production and Consumption

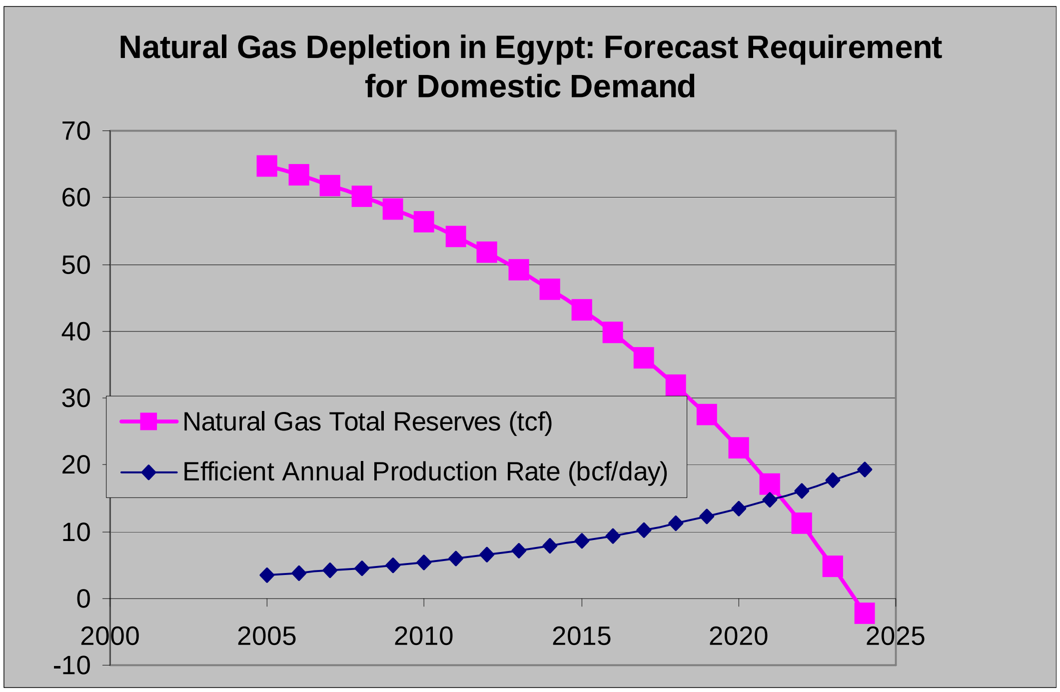
Egypt's natural gas sector has been expanding rapidly, and production nearly doubled from 1997 to 2002. Production stood at more than 3 billion cubic feet per day (bcf/d) from 1.6 bcf/d in 1999, and is expected to reach 7 bcf/d in 2006. Output from the Abu Madi and Badreddin fields accounts for more than half of the country's production. Consumption, in the past, has been almost identical to production, at 98.5% of production capacity in the last 15 years. The future is expected to look very different because of export prospects. However, based on energy demand, the consumption of natural gas in Egypt is expected to reach almost 60 (million tons oil equivalent units). Yearly increases are estimated at 9.45% annual growth rate of natural gas demand for domestic consumption until the year 2015. Hence, if Egypt will count on its export revenues of natural gas in the future, it must expand production beyond the stated 9.45% annual growth rate.



Source: Primary Data from Information and Decision Support Center, Government of Egypt

Egypt has been increasing domestic gas demand by converting its power plants to run on gas. Thermal power plants account for about 65% of Egypt's total gas consumption. Large industrial consumers have also been switching to gas, including petrochemical plants, a large new fertilizer plant in Suez, and several major new steel projects in Alexandria, Suez, and south of Aswan. Some 20,000 taxis in Cairo have been modified to run on CNG as part of a pilot program. The construction of (17 CNG) service stations are supporting the project. Egypt is trying to improve the availability of natural gas for residential customers by allocating service areas to several private companies, a program which started beginning of 1998. British Gas heads a group that includes Orascom (an Egyptian construction firm), and Edison International SpA that runs to invest $220 million in a distribution network to serve Upper Egypt down to Assyout, an area with no existing gas service. The network may be expanded as far south as Aswan.

On the production side, although Egypt's proven reserves of 66 tcf seem to the typical citizen as an abundance of a natural resource, production scales must grow annually to meet forecasted demand, and that will cause resource depletion. It is estimated that an average depletion rate of 3.38 tcf per year must occur as a lower bound estimate based on demand and supply forecasts. This corresponds to a minimum of 801,200 cf of added production volume every year. This is the efficient annual production rate of natural gas based on lower bound estimates of thermal energy content and the subsequent growth of energy demand consumption. Consequently, such a resource depletion rate will cause absolute resource scarcity of Egypt's current proven natural gas reserves by the year 2024.



Gas Market Exploration

A decision by the government to form joint ventures with private companies and pay the world price for gas from any discoveries served to encourage exploration beginning in the late 1980s and early 1990s. This incentive led to major discoveries of gas deposits in the Nile Delta and Western Desert. However, these discoveries turned out to be a mixed blessing for Egypt -- the Egyptian government had to pay the going market price for gas that it was not using, and was unable to export this unused gas because it lacked the necessary infrastructure to liquefy or export any surplus natural gas. A remedy was finally implemented in November 1999, when the Egyptian government decided to allow the producers themselves to export the gas.

That decision spurred the creation of even more joint ventures between the government and the private sector. Gupco announced plans in March 2000 that would raise Egypt's gas production from 1.8 bcf/d to 3.8 bcf/d by the end of 2000, by starting operations at the Hapy Gas Field. In April 2000, BP-Amoco announced a deal with EGPC to build a gas treatment and separation facility around the Gulf of Suez. The Anglo-American Company plans two complexes on the Mediterranean coast to process and ship liquefied natural gas (LNG) throughout the region. Shell will cooperate with EGPC to explore for gas offshore in the Mediterranean. The two companies plan to have two wells online in 2000 or early 2001 with three more to follow. EGPC has agreed to supply a new LNG plant in Edku, east of Alexandria with gas from the West Delta Deep Marine Concession. The plant will be owned and operated by EGPC, British Gas and Edison International SpA.

The top six foreign energy companies involved in Egyptian gas exploration and production in terms of reserves are ENI-Agip, BP, British Gas, Shell, Edison International SpA, and Repsol-YPF (in June 1999 Repsol acquired Argentina's YPF.) With the exception of Repsol-YPF, all plan significant investments in the future. Shell has plans to spend around $1.6 billion on gas exploration and development. BP-Amoco plans to spend $450 million, while ENI-Agip and BG also plan significant expenditures in this area. As part of Repsol-YPF's debt reduction plan since taking over YPF, Repsol-YPF also agreed to sell its stake in three oil and gas exploration and production blocks in the Nile Delta to Germany's RWE-DEA for $80 million. Likewise, Repsol-YPF recently sold its Egyptian interests to Apache Corp. for $410 million. The acquisition raises Apache Corporation's interest in the Khalda concession to 90%, and it has become the operator of the concession.

The Obeiyed and Khalda areas in the Western Desert have shown great potential for further increasing Egypt's gas production in the near future. The Obeiyed Field recently started producing 300 million cubic feet per day (MMcf/d), after the completion of a pipeline linking it to Alexandria. Production of 300 MMcf/d has also started at Khalda, and the output from Obeiyed and Khalda will be transported to Alexandria by a 180-mile pipeline.

The International Egyptian Oil Company (IEOC), an ENI-Agip subsidiary, is the country's top natural gas and overall hydrocarbons producer with operations in the Western Desert, the Gulf of Suez, and the Nile Delta. It has teamed up with BP-Amoco to invest $1 billion in exploration and development of natural gas reserves in the Nile Delta region. Both companies hope their efforts will yield about 365 bcf per year.

In November 1997, BP-Amoco, EGPC, and IEOC reported a $248 million development plan in the Hapy Gas Field in the Ras el-Barr Concession. It is estimated that multiple Nile Delta investments will yield up to 2.0 tcf per year. The IEOC, in cooperation with BP-Amoco, ENI-Agip, and EGPC, announced plans to invest $700 million to develop the Temsah Gas Field also in the Nile Delta. Gas reserves at Temsah are estimated at 3.9 tcf. The deal calls for gas sales to begin at 35 MMcf/d and increase to 480 MMcf/d.

The Nile Delta is home to other recent discoveries such as the Sigan-1 field by Petrobel, Wakkar by ENI-Agip/EGPC, and Rosetta-5 and Rosetta-6 by British Gas. Germany’s RWG-DEA discovered gas at its concession in the Nile Delta, with a flow rate of 30 MMcf/d. Italy's Edison International SpA (not affiliated with the U.S.'s Edison International) and British Gas made a significant discovery in May 1999 in the West Delta Deep Marine Concession, with a flow rate of 45 MMcf/d. A month later, the companies tested Simian 1 at 44 MMcf/d.

Egyptian hopes for more natural gas discoveries are brightened by tests suggesting that the same geological formations that contain gas in the Nile Delta stretch into the Mediterranean Sea due to the flow of the Nile River.

Exports

Egypt currently consumes most of its natural gas production, but the host of deepwater discoveries offshore Egypt are starting to look more commercial. Turkey, Israel, Jordan, Libya, and the Palestinian territories have been mentioned as possible export markets. In December 1999, an agreement was reached with Israel to build a gas pipeline from El-Arish in the Sinai to Israel and Gaza by 2002. The pipeline would eventually go on to Lebanon, Syria, and Turkey. However, Israel has since become optimistic about offshore gas discoveries in its own waters and has frozen talks to import Egyptian gas until it can better gauge the size of its reserves.

The rapid rise in natural gas reserves has led to a search for export options, which has become particularly important to Egypt's future international balance of payments due to the decline in oil exports. In late 1999, the Egyptian government stated that natural gas reserves were more than sufficient for domestic needs, and that foreign firms producing gas in Egypt should seek export customers. In early 2000, the government announced a moratorium on new purchase agreements by EGPC for domestic consumption, as previously signed agreements would meet projected demand for the next several years. It also announced in September 2000 a new pricing policy which includes ceiling and floor prices, designed to protect both consumers and producers from the risks of prices indexed to oil.

The idea of exporting natural gas to Israel has been under discussion since the mid-1990s, and after being sidelined for several years by the Israeli-Palestinian violence which began in late 2000, seems to again be under serious consideration. The original version of the plan would have involved construction of an offshore pipeline from El-Arish in Sinai up the coast of Israel, with a possible extension onward to Turkey. The East Mediterranean Gas Company (a consortium of EGPC, Merhav of Israel, and Egyptian businessman Hussein Salem) had been set up to pursue the project. ENI completed a pipeline up Egypt's Mediterranean coast to El-Arish, which could serve as a starting point for the export pipeline. This would involve a short offshore pipeline to Ashkelon from northern Sinai, bypassing Gaza. A framework agreement between the two governments was concluded in February 2005, and negotiations for a binding natural gas sales contract with the Israel Electric Corporation (IEC) are underway.

Another export pipeline to Jordan began commercial operation in July 2003, making possible Egypt's first exports of natural gas. Egypt was responsible for building the section from the existing pipeline terminus at El-Arish to Aqaba in Jordan, with a sub sea section in the Gulf of Aqaba bypassing Israeli waters. Construction of the section of the pipeline from Aqaba to northern Jordan is being undertaken by a Jordanian firm, the Al-Fajr Company for Natural Gas Transportation. Egypt, Jordan, and Syria agreed in principle in early 2001 to extend the pipeline into Syria, with eventual natural gas exports to Turkey, Lebanon, and possibly Cyprus. The feasibility of this option is questionable, though, as Turkish demand probably would not support another source of piped gas (beyond agreements in place with Russia, Azerbaijan, and Iran). A more modest version of the plan could include the addition of pipeline links to only Syria and Lebanon.

Egypt's other option for exports is LNG. Two LNG projects are currently underway. The Spanish firm Union Fenosa is building a two-train liquefaction facility at Damietta, which shipped its first cargo in January 2005 upon the completion of the first train, with a capacity of 268 Bcf per year. Unlike most previous LNG projects, this one is not tied in directly with upstream natural gas production. Union Fenosa has contracted with EGAS for the supply of natural gas from its distribution grid, and will take 60 percent of the LNG output itself for use at the company's power plants and distribution to other users in Spain and elsewhere in Europe. ENI also has become involved in the project, purchasing a 50 percent stake in Union Fenosa's natural gas business in December 2002. BP signed an agreement for sales of natural gas from its offshore fields to supply the second train at Damietta in July 2004.

The second LNG export project ("Egyptian LNG"), at Idku, is to be built by BG in partnership with Petronas. The project is tied in to natural gas reserves from BG's Simian/Sienna offshore fields, and began production ahead of schedule in March 2005, with a second liquefaction train becoming operational. Gaz de France is to be the main off taker for the Idku LNG project's first train, having signed a contract in October 2002 for 127 Bcf per year beginning in 2005. An agreement to purchase a similar quantity of LNG from the second train was signed in September 2003 by BG LNG Services. The

LNG will initially be delivered to the Lake Charles, Louisiana import terminal for the U.S. market, starting in mid-2006. Later, probably in 2007, BG will switch the output from Idku to an import terminal at Brindisi, Italy, and use additional production from Trinidad to supply the Lake Charles terminal. BP and Shell both are also contemplating potential LNG projects in Egypt (EIA, 2005). Another potential use for Egypt's natural gas reserves is gas-to-liquids (GTL) projects. Shell has proposed a 75,000-bbl/d GTL plant to be co-located with its LNG export terminal when it is built, using reserves from its offshore NEMED find as feedstock. No final agreements have yet been reached on the proposal (EIA, 2005).

6. COMPARATIVE ANALYSIS: OIL AND NATURAL GAS IN EGYPT

Egypt’s proven oil reserves are estimated close to four billion barrels, and the government released an estimate of probable crude oil reserves at 8.2 billion barrels, based on expected new finds and increased recovery ratios. As at 1 January 2006, Egypt’s proven crude oil reserves are estimated at 3.7 billion barrels (APRC, 2003, p.12, p.94). On the other hand, for natural gas, there exist vast reserves with a strong potential for more discoveries. Beginning in the early 1990s, foreign oil companies began more attractive exploration for natural gas in Egypt, and very quickly found a series of significant natural gas deposits. Proven reserves stand at 66 trillion cubic feet (tcf) in 2006 with probable reserves estimated at 120 tcf and some estimates set the probable reserves figure up to 180 tcf.

On the production side, Egyptian oil production in 2005/2006 reached almost 700,000 barrels per day (b/d), down sharply from a peak in 1996 of 922,000 b/d, but only modestly above the 631,000 b/d in 2003/2004 (AmCham, 2003, p12). Natural gas production stood at more than 3 billion cubic feet per day (bcf/d) in 2004/2005, and is expected to reach 7 bcf/d by end of 2006.

On the consumption side, domestic demand for oil has been climbing from 501,000 b/d in 1996 to 585,000 b/d in 2000 due to rapid economic growth during this period. Then it reaches a peak in 2003 at 566,000 b/d, and is rising close to another peak of 590,000-600,000 b/d in 2006. The sharp increase in local oil consumption over the past decade can be attributed to two factors: (1) procyclical economic growth cycle, and (2) over-consumption due to subsidies. The late 1990s contributed to higher oil needs due to a procyclical demand for oil, whereas government subsidies created over-consumption as most oil products are subsidized by the government to prevent rising prices (AmCham, 2003, p.19).

With respect to natural gas, there has been an increase in domestic demand by converting Egypt's power plants to run on gas instead of oil, in addition to the rise in population. Thermal power plants account for about 65% of Egypt's total gas consumption. Large industrial consumers have also been switching to gas, including petrochemical plants, a large new fertilizer plant in Suez, and several major new steel projects in Alexandria, Suez, and south of Aswan. Egypt is currently adopting a gas price formula where gas is linked to oil with a ceiling and a floor. However, government has been pushing to formulate a new gas price formula independent from oil.

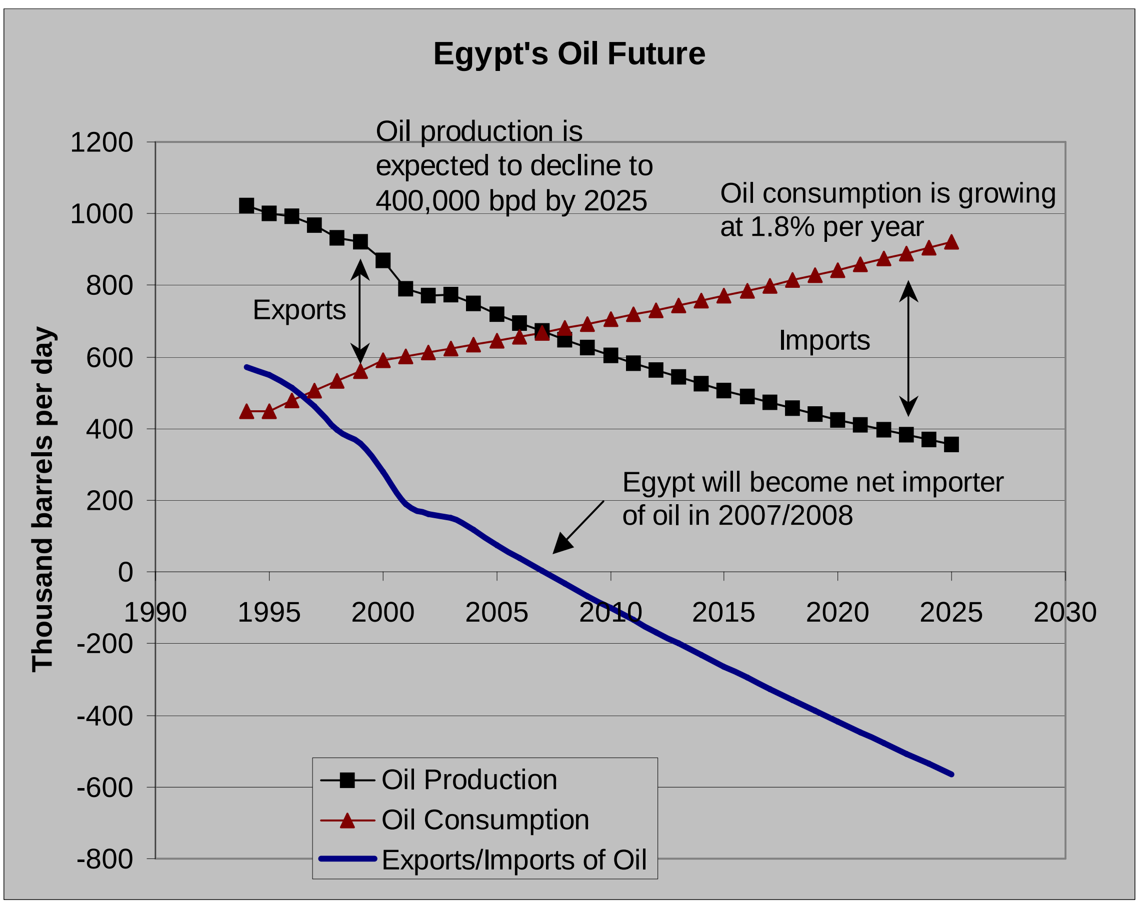
In this study, different economic sensitivity analysis have been conducted on oil and natural gas. Those were based on the assumptions of historical population growth rates, future growth in domestic demand (demand-driven market analysis), and static elasticity over time. Dynamic analysis was conducted to reach the rate of resource depletion based on annual resource extraction rates (annual efficient production levels).

For price elasticities, it was found that demand price elasticity for oil is 0.02, while it was found to be 0.26 for natural gas. Hence, oil is completely price inelastic, whereas natural gas is price inelastic. Thus, for the case of oil, prices are not a key factor in the pattern of domestic consumption over time. This is mainly due to government subsidization efforts. This has also been shown analytical by a significant positive income elasticity. Since both oil and natural gas are price inelastic, both are considered necessary goods in consumption. Moreover, oil is considered completely price inelastic (it is very difficult to be substituted) probably due to its importance as a necessary input in most of Egyptian industries. Hence, there exists a "resistance to change" on the part of consumers for a significant price increase in oil. Even for natural gas, if price increases by a significant 10%, domestic consumption will decline by a small 2.6%.

A note should be mentioned concerning subsidies as it relates to oil and natural gas. Since demand for oil is more price inelastic, the lifting off of oil subsidies will not be associated with a substantial reduction in oil consumption. Yet, since oil is a necessary good, the sudden lifting of subsidies will generate a loss in annual savings and/or an increase in poverty in the population. Citizens on the margin of poverty (secondary poverty) will find themselves beneath the poverty line. On the other hand, concerning natural gas, since its price elasticity of demand is more elastic compared to oil, then this directly means that over-consumption of natural gas (due to a subsidy) is more intense than that of oil. Thus, if demand preferences stay constant in the future, it is desirable to start lifting off natural gas subsidies rather than oil subsidies, since the former will save more energy resources for the economy than the latter.

With respect to income elasticity, it was found that income elasticity for oil is 0.43 whereas that of natural gas is 1.4. Consequently, relative to income levels and associated budget expenditures of households, oil is a necessary good whereas natural gas is a normal good. A rise in income is associated with more demand increase for natural gas than that of oil. It is also estimated that the social losses (additional economic burden) per Egyptian household from totally lifting oil subsidies will be LE 110 per month per household. This is a substantial portion of a typical citizen's annual average income. Hence, the removal of oil subsidies, when undertaken, should be timed out in phases. In addition, expected inflationary pressure from the lifting of oil subsidies should be addressed. It is estimated that a total elimination of oil subsidies will cause an additional five to seven percentage points of inflationary pressure on the economy based on multiplier effects of higher commodity prices for most essential goods due to higher input costs and higher transportation costs across the supply chain. The political economy and real sector adjustments to this inflationary pressure must be accounted for even within a strategy of gradual removal of oil subsidies.

The relationship between oil and natural gas to value of GDP was also estimated. It was found that sensitivity of oil/GDP ratio is 0.3 whereas that of natural gas is 0.9. The weighted average of energy elasticity to GDP is 0.5. Consequently, the decomposition of energy to GDP impact ratios yield an oil impact ratio of 67% and the impact share of natural gas at 33%[16]. This has important repercussions on target GDP growth rates and exports. In essence, target GDP growth rates will necessitate energy demand growth at 1.8% annually for oil. With an expected oil production decline of 3.4% annually, this means that Egypt's oil imports must average an increase of 5.2% annually. Hence, it is projected that Egypt will become a net importer of oil by 2007, with net oil shortages reaching 100,000 bpd in 2008, 300,000 bpd in 2015, and as high as 600,000 bpd in 2025.



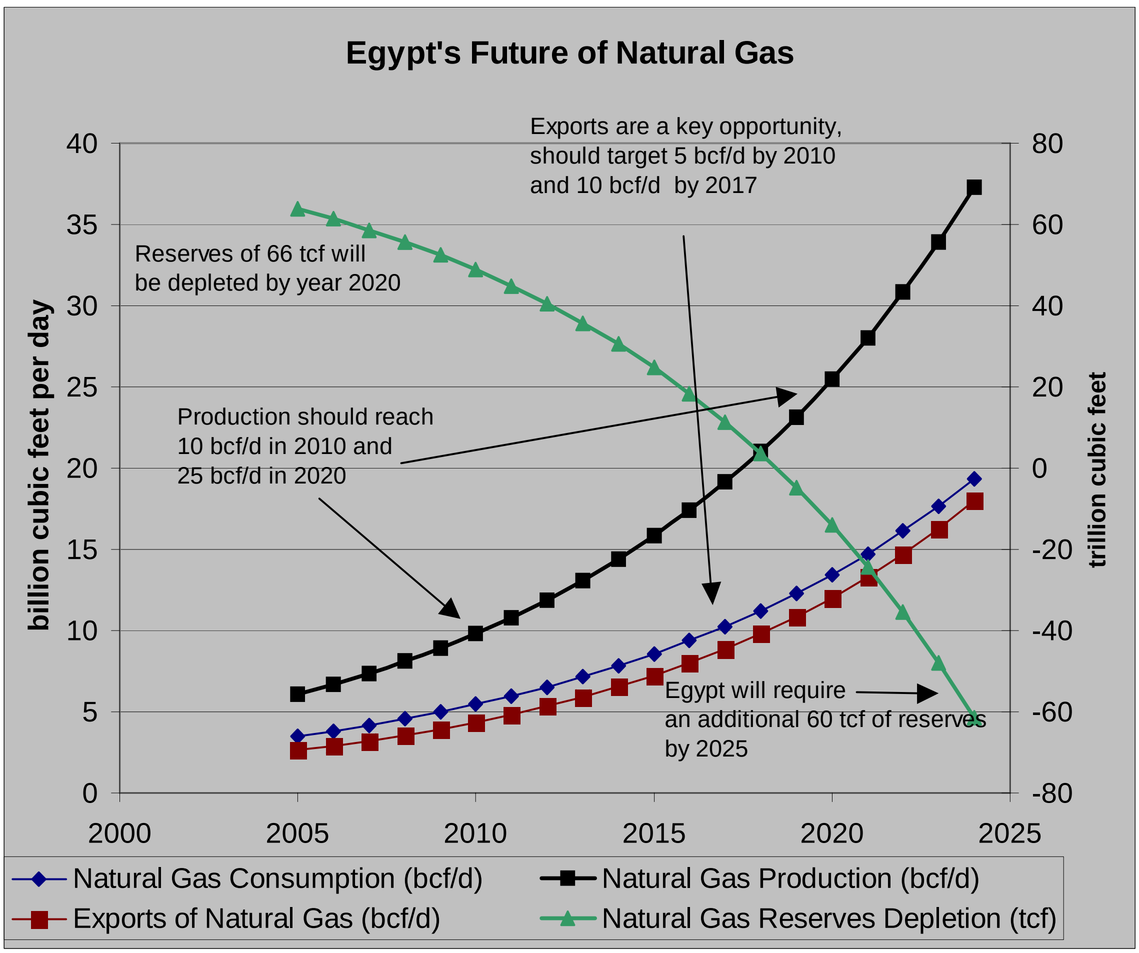
[16] Energy/GDP impact of 0.5 is decomposed into the respective elasticities of oil and natural gas

$$0.3\eta^{oil} + 0.9\eta^{gas} = \eta^{energy} = 0.5$$

Comparative Table: Oil and Natural Gas in Egypt

	Oil	*Natural Gas*
Reserves	A decline in reserves. Total proven reserves at 3.7 billion barrels.	Vast reserves with strong potential for more discoveries. Total proven reserves at 66 trillion cubic feet.
Production	A decrease in production due to subsidization, technical reasons and recent decline in reserves.	Production has doubled due to increase in reserves, increase in demand, and as a substitute for oil as it is environmentally friendly.
Consumption	An increase in consumption due to economic growth and subsidizing.	An increase in domestic demand mainly due to thermal power plant conversion.
Pricing	Pricing is based on international prices, but is subsidized for all income groups.	Natural gas price has been artificially linked to oil with a ceiling and a floor using a certain gas price formula.
Price Elasticity	Demand price elasticity is 0.02 (completely inelastic).	Demand price elasticity is 0.26 (inelastic).
Cross Elasticity	Cross elasticity between oil and gas > zero, they are substitutes.	
Income Elasticity	Income elasticity is 0.43 which shows that it is a necessary good.	Income elasticity is 1.4 (normal good).
Areas of Production	70% from the Gulf of Suez, 16% from the Western Desert, 7% from the Sinai Peninsula and 6% from the Eastern Desert.	The Nile Delta, The Western Desert and under the Mediterranean Sea.
Main Players	EGPC (state-run), Gupco, Petrobel, Badr el-Din Petroleum Company, El Zaafarana Oil Company and Shell.	EGPC (state-run), IEOC, Eni-Agip, BP-Amoco, British Gas, Shell, Edison, International SpA and Repsol-YPF.
Transportation	Suez Canal and Sumed Pipelines.	Pipelines.
Exports	A decline in exports due to increase in local consumption accompanied by a decrease in production.	Beginning of exports in 2004/2005 looking for new opportunities after the recent increase in its reserves.
Elasticity of Substitution	It was found that the elasticity of substitution between oil and gas in production is 3.4; while the elasticity of substitution in consumption is 4.06.	
Energy/GDP elast.	Oil/GDP elasticity is 0.3.	Natural Gas/GDP elasticity is 0.9.

The future of natural gas in Egypt looks bright. Even though consumption of natural gas is expected to rise steeply with time until 2025, production can overcome such demand and also produce a sizeable volume of exports. Consumption is expected to rise by nearly 9.45% annual growth rate per year due to combined effects of population growth, output growth (GDP growth), and the transition from oil to gas in thermal power generation. However, production is expected to reach 7 billion cubic feet per day (bcf/d) in 2006, and economic policy should target a production rate of 10 bcf/day by 2010 and 25 bcf/d in 2020. In retrospect, exports are a key opportunity for natural gas in Egypt. Egypt should be able to deliver a export volume of 5 bcf/d by 2010 and 10bcf/d by 2017.



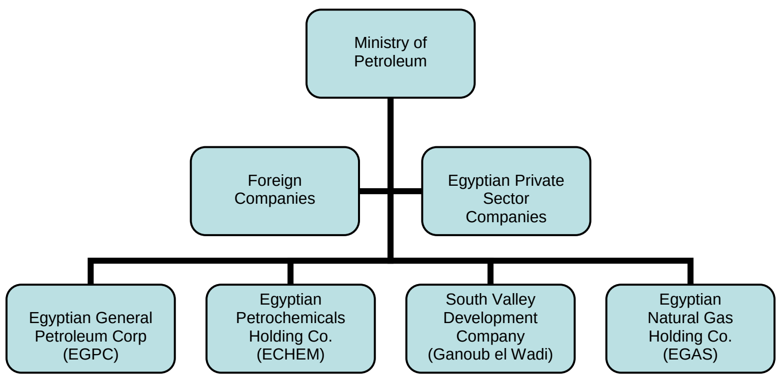
The author believes, based on sustainability calculations, that Egypt's proven reserves of 66 trillion cubic feet should be depleted by 2020, and that the economy will require an additional 60 tcf of additional reserves of natural gas by 2025. These additional reserves are within the probable reserve endowment of the country by current standards (120-180 tcf of probable reserves are the current estimate). This, of course, will require complementary investment costs associated with exploration and resource distribution. However, expected profit margins of 20% are expected to persist with time, conditional on economies of scale in production.

Comparison Table: Future Outlook for Oil and Natural Gas in Egypt until 2025

	Oil	***Natural Gas***
Consumption Growth	1.8% average annual growth rate until 2025.	9.45% average annual growth rate until 2025.
Production Targets	Oil production is expected to decline to 400,000 bpd by 2025, with annual production decline of 3.45%.	Production should reach 10 bcf/d in 2010 and 25 bcf/d in 2020.
Exports	An oil shortage is expected by 2007.	Exports are a key opportunity. Gas exports should be able to reach 5 bcf/d by 2010 and 10bcf/d by 2017.
Imports	Required imports of oil at 100,000 bpd in 2008, 300,000 bpd in 2015, and 600,000 bdp in 2025.	No required imports of natural gas are expected.
Pricing	Phased relaxation of oil subsidies are expected. Persistence of consumption characterized as a necessary good.	No gas subsidy changes are expected. Consumption will remain characterized as a normal good.
Profit Margins	High profit margins at approximately 70%.	Low profit margins at approximately 20% conditional on economies of scale and associated investment costs.
Reserves	3.7 billion barrels. Additional reserves will reduce import requirements.	66 trillion cubic feet. Expected depletion by 2020. Probable reserves at 120-180 tcf.
Risk	Impact on balance of trade (deficit).	Low risk.
Environmental Impact	High carbon emissions (clean technology needed to meet Kyoto Protocol standards).	Low carbon emissions.

7. STRATEGIES FOR EGYPT'S ENERGY SECTOR:

The Egyptian government, represented by the Ministry of Petroleum and its different agencies, exerts full control over the energy industry in Egypt, and has a tight reign over all concessions (whether for exploration, refining or selling). The following diagram[17] outlines the energy agencies concerned with the structure of the oil and gas industry in Egypt:



Source: American Chamber of Commerce

Hence, economic policy takes a top-down approach with a centralized focus when dealing with energy policy in Egypt. This is particularly important when attempting to recommend certain strategies for future industry needs. The government attempts to exercise this centralized control through granting of oil concessions to private and foreign firms.

An oil concession can be public or private, and is a contract between the government and the exploring company, known as the concessionaire, which gives it the right to explore, produce, export and sell any oil or gas that it discovered in the field under concession, during the duration of the concession period. The concession also outlines all the legal aspects of both parties i.e. their rights and responsibilities.[18] Oil concessions are granted

[17] Am Cham, Ibid.p.9.
[18] H. Cattan: The Law of Oil Concessions in the Middle East and North Africa, Oceana Publications, Inc., Dobbs Ferry, New York, 1967, p. 20.

after a competitive bidding process and legislative approval. Unfortunately, these procedures are bureaucratic in nature, take considerable amount of time, and do not have any specified deadline. This could be one of the main practical reasons why oil and gas resource extraction have been under-utilized, and therefore under-depleted (see Appendix), in Egypt's historical past.

The petroleum industry in Egypt is considered to be one of the major development catalysts in the economy mainly due to the interest that it has stirred in investors, and not particularly because of employment generation. Hence, physical capital requirements are key to the future growth of the industry, especially as those are related to economies of scale and reduction in unit production costs (thus creating what has been commonly known as "Stein's competitive advantage"). In retrospect, due to world energy market trends, resource endowments of energy resources are only necessary, but not sufficient, conditions, to impact long term development. In addition to resource endowments (comparative advantage), a sustainable element of competitive advantage must be present. This is achieved by process innovations yielding cost-reduction advantages in the energy industry supply chain in comparison to other countries.

In Egypt, local investments in the petroleum industry recently amounted to around L.E. 7.8 million ($1.7 million) while foreign investment was around $2.1 million. However since the oil and gas industry is a capital intensive industry, manpower in crude oil was only 33,300 workers in 2004, and in oil products was slightly less at around 30,300.[19] It should be noted however, that since energy is a highly capital intensive industry, it does not hold the key to Egypt's unemployment problem which lies in the range between 10% (official figures) and 15% (unofficial estimates) (World Factbook, CIA, 2006).

The oil and gas sector fulfils around 95% of Egypt’s energy requirements, distributed between oil (53%) and natural gas (42%).[20] Electricity generation is the highest consumer of gas (62.4%), followed by manufacturing industries (26.2%), petrochemicals (9.4%)

---

[19] Accessed 6.11. 2005.
[20] Am Cham, Ibid, p.8.

and residential and commercial users (2%).[21] Egypt's energy resources are therefore predominantly demand driven by thermal power generation, and supply driven by amount of proven reserves.

Due to the discoveries of substantial natural gas reserves, Egypt currently has a potential comparative advantage. This should be further developed into a competitive advantage so that export potential is maximized to the fullest extent possible. In particular, as previously mentioned, Stein's competitive advantage (reduction of unit costs with time through process innovations) can deliver promising future results. This requires technology transfer with local process innovation, which is not one of the main characteristics of the Egyptian human development scene in general (World Bank, 2005).

It is ironic to note that oil and gas will be complementing each other in Egypt. Whereas oil production is now dwindling in view of maturing oil fields and reduction in reserves, gas production by contrast is enjoying a sustainable future growth trend which has not yet reached its peak. Hence, both resources complement each other for Egypt's future energy needs. This requires a change of general strategy from oil being the strategic energy resource in the economy, towards a new strategy whereby natural gas should be considered the new strategic resource instead of oil.

Future energy policy should be built upon this shift of strategy.

One of the main critiques of the oil and gas industry is its high level of subsidies. Prices are extremely distorted and do not reflect international prices. Furthermore, subsidies carry with them a huge amount of public debt as well as external debt. The government announced in its 2004 budget that it has spent around L.E. 14 billion to cover petroleum subsidies (1 US$ is equivalent to 5.7 L.E.).[22] Furthermore, since the oil and gas sector is heavily subsidized both to consumers as well as to intermediate industries, the oil and gas sector actually partially subsidizes all productive activity in the Egyptian economy[23]. And while Egypt faces falling oil production from its mature oil fields, and hence declining

[21] UNDP: http://www.undp.org/Egypt
[22] Am Cham, Ibid, 43.
[23] "*Apache Egypt's Contribution to the Egyptian National Economy*", Ibid, p.28.

revenues in spite of increasing international oil prices, domestic consumption will force it to become a net oil importer by 2007 as analysed in this paper. Unless Egypt reforms its existing pricing mechanism in the oil sector it would further augment a chronic problem. Moreover, the lifting of oil subsidies is desirable to be implemented in phases as have been discussed in previous analysis, in order to contain inflation and hedge against increasing rise in poverty. However, as have been estimated in this research, since oil is almost completely price inelastic, economic policy should not expect a sizeable reduction in oil consumption even when subsidies are lifted. Regarding natural gas, it is the view of the author that subsidizing natural gas, an abundant resource in the economy, should and will continue in the near future.

The following table summarizes general expectations for the oil and gas industry in Egypt:

COMPETITIVE POSITION **Comparative advantage in natural gas** **X-inefficiency in oil production**	**INDUSTRY POTENTIAL** **Stein's competitive advantage** **Large investment costs** **Low employment generation**
RISK POSITION **Substantial public debt problems** **Balance of trade deficit (moderate risk)** **Middle East regional war (low risk)** **Inflationary pressure (high risk)**	**INDUSTRY OUTLOOK** **Oil shortage (oil imports)** **Gas surplus (gas exports)** **Reduction of oil subsidy (in phases)** **Continuation of gas subsidy**

Based on the previous analysis, the energy sector in Egypt will need major restructuring. In the remainder of this section, numerous suggested strategies and their expected impact for restructuring will be outlined and discussed in some detail.

P R O P O S E D S T R A T E G Y	E X P E C T E D I M P A C T
1. POLICY SHIFT FROM OIL TO GAS AS THE STRATEGIC RESOURCE	
Re-orient future energy policy towards gas as the new strategic resource instead of oil. Efficient depletion of natural gas reserves based on sustainable growth requirements (energy growth requirement of 3% a year based on GDP growth rate of 6% a year). Target investments for natural gas production at $12 billion per year, over the next ten years (2006-2016) Efficient utilization of scarce oil deposits, with oil imports starting in 2007. Exporting of natural gas (as a future opportunity) by targeting an export rate of 5 bcf/d in 2010 and 10 bcf/d in 2017. Importing of oil (as a future requirement), starting 2007, with a strategy of oil storage when import prices are low. Reduce X-inefficiency in oil production. Reduce overconsumption of oil (minimum reduction targets of 7,000 b/d in 2010 and 10,000 b/d in 2025). Achieve competitive advantage in gas exports through process innovations based on a cost-reducing strategy, while maintaining a target profit margin of 20%.	Natural gas production expansion from current 7 bcf/d to 35 bcf/d phased out until 2025 Large investment costs required to achieve economies of scale in gas production (1 bcf/day capacity requiring $1 billion in investment, whereas 479 mcf/day requiring $700 in investment) Natural gas reserves of 66 tcf (proven) will be depleted by 2020 Expected annual production decline of oil by 3.45% a year Consumption growth of about 2% for oil and about 9% for natural gas (annually until 2020) Required imports of oil reaching 100,000 bpd in 2008, 300,000 bpd in 2015, and 600,000 bdp in 2025 Shifting of oil to gas in domestic power plants can improve Egypt's position to meet carbon emissions (Kyoto Protocol) standards Phasing out of oil subsidies and continuation of gas subsidies.

PROPOSED STRATEGY	EXPECTED IMPACT
2. REDUCTION/REMOVAL OF OIL SUBSIDY	
Gradual reduction of oil subsidies with continuation of gas subsidies in the near future.	Increased potential of secondary poverty (in excess of 40%)
Set long-term date to eliminate energy subsidies (20 year horizon).	Persistent consumption of oil due to very low price elasticity (0.02)
Establish a welfare system through the conduct of a comprehensive survey system to determine income status of the population and accordingly allocate aid (monetary or in kind) to those in need of an oil subsidy.	Elimination of price distortions in local market Reduction of public debt (by at least LE 140 million in 2004 real terms due to elimination of overconsumption)
Enforce labor law (minimum wage level) to minimize secondary poverty effects, with a suggested minimum wage of LE 342 per month for 35 working hours per week.	Inflationary pressure of an additional five to seven percentage points after the full removal/withdrawal of subsidies
Enforce progressive registration tax on expensive automotive vehicles to be levied until the oil subsidy is removed.	Government with require needed information infrastructure to target those in need Decreased household budgets by approximately LE 110 per month (in 2005 real terms) Ironing out share of the high income groups from the energy subsidy

PROPOSED STRATEGY	EXPECTED IMPACT
3. ADOPTION OF RENEWABLE RESOURCE TECHNOLOGY	
Draft and implement legislation in the New and Renewable Energy Authority (NREA) in support of renewable resource technology, especially solar energy.	Indicates a serious, high-level government support for solar/renewable energy use
Ensure low import trade barriers on solar and wind technology, in substitution for oil.	Gradual establishment of a domestic renewable energy market (evolutionary market growth at 1.75% a year for 20 years)
Launch marketing campaign for solar/wind energy in Egypt, in substitution for oil, by targeting a 5% energy use by 2010, 10% by 2015, and 25% by 2025 (currently <1%).	Foreign technology transfer
Initiate technology training programs, and subsequent development of NRE curriculum, R & D, S & T in local universities.	Raise consumer and entrepreneurship (risk taking) awareness
Egyptian government should undertake to use a fixed portion of its revenues (subsidy savings and/or increased taxes) in domestic renewable energy infrastructure.	Augment the "social resistance to change" argument
Provide economic incentives to convert from oil to Compressed Natural Gas (CNG) – power plants, industrial units, public transportation and vehicles, in line with gradual removal of oil subsidy.	Lowering domestic oil consumption by substitution of renewable energy use (oil reduction targets of 35,000 bpd in 2010, 80,000 bpd in 2015, and 225,000 bpd in 2025)
Promote new domestic markets for solar and wind technology by utilizing tax holidays.	Enhance human capital development based on local innovation
Incorporate solar technology into public construction schemes.	Improve environment (reduction of pollution) with potential gain of $130 per ton of carbon emissions reduction

P R O P O S E D S T R A T E G Y	E X P E C T E D I M P A C T
4. ATTRACT LOCAL & FOREIGN INVESTMENTS Provide incentives for private local and FDI entry into the energy industry in Egypt relative to other countries. Total investments in natural gas reaching $220 billion for the next 15 years, averaging $14.6 billion per year in 2005 real terms. Pricing of oil at international market prices. Formulate overall long term industrial plan with the collaboration of all relevant ministries. Increase government transparency via marketing campaign, complete knowledge/information, e-marketing, availability of free updated information. Reduction of bureaucracy and lengthy procedures (reduce transaction costs and eliminate existing hidden costs).	Economies of scale with lower unit costs in production Reduce investment uncertainty Ensure investor has a comfortable profit margin in line with international industry standards (70% PM for oil, and 20% PM for natural gas) Ensure the implementation of ambitious investment schemes with private & public sector collaboration Enhance capital accumulation with positive impact on economic growth (0.5 as energy/GDP elasticity) Expand FDI involvement and subsequent transfer of technology (limited impact) Additional job creation (reduction of the unemployment problem in Egypt, although such an impact is expected to be subtle) Increased market competition should impact local incentives for process innovation, reaching Stein's competitive advantage relative to other nations

The Egyptian government carries an inherited legacy of half a century of subsidization of basic goods and services. This has become the trademark of the social contract between the state and the Egyptian citizen. In Egypt a thirty-multiple fold income gap exists between the highest and lowest quintile, and the fact that more than 40% of all Egyptian households are considered poor (living below $2 per day),[24] makes subsidies of vital importance to their very existence and their access to affordable energy[25]. However, the strategy suggested above is a gradual transition of oil subsidies over a twenty year horizon. This strategy should generate a more sustainable energy production and better distribution mechanisms at the local level.

The oil subsidy has the following implications: (i) The differential between the international price and the energy subsidy negatively impacts Egypt's public debt. The high levels of demand at artificially low market prices merely serve to increase debt, and in Egypt's case, public debt already exceeds 102% of 2005 GDP[26], a figure which does not leave many alternatives to a policy of strict fiscal austerity; (ii) The artificially low price encourages over-consumption of an already scarce resource compared to the case if consumers were paying real prices of oil; (iii) The increase in domestic consumption, which constantly grows at local production and hence reduces export potential, denies Egypt's potential export revenue; (iv) Egypt will actually become a net importer of oil, with the obvious negative implication on its balance of trade; (v) Oil is a primary source of energy and necessary input for other industries, which further complicates the problem throughout the whole economy.

Another implication on welfare is the pollution caused by the exhaust emissions and their adverse effects on the environment. The urban environment in developing countries is a magnet for heavy pollution and low human health indicators. Recommended strategies should take environmental concerns into consideration. As stated objectives of the Ministry of Energy and Electricity (MEE) and the New & Renewable Energy Authority (NREA), those agencies should aim at converting domestic energy consumption from

[24] UNDP, Egypt Human Development Database.
[25] Ibid.
[26] CIA World Factbook, 2006.

dirtier resources, such as crude oil, to cleaner and more environmentally sound resources, such as CNG, liquefied natural gas (LNG) and renewable resource technology. The discipline of renewable resource technology parallels a growing interest in the social cost of pollution. A recent project estimated that the monetary value of carbon dioxide pollution was between LE 358 to LE 1,738 per metric ton of carbon emissions.[27] Encouragingly, Egypt has one of the lowest carbon dioxide emission rates in the MENA region because of its hydroelectric capacity, claiming only 127 million metric tons of CO_2 emissions in 2002.[28] Although the Egyptian Ministry of Petroleum has adopted a strategy aimed at environment preservation and protection, and signed the Kyoto Protocol of the United Nations Framework Convention on Climate Change, it has yet to enforce that protocol to control carbon emissions.[29] To counteract the exhaust problem, the "Pigouvian Framework" could be put into practice whereby polluters are penalized for their activities either by denying them registration until they remedy the problem or enforcing penalty taxes.

Dramatic increases in energy demand are an inseparable externality to economic growth. Particularly in developing countries, a 10% increase in disposable income often equals as much as a 20% increase in electricity consumption, and a 15% increase in natural gas consumption alone.[30] Thus, the reverse is also true: opportunities for economic growth require higher demand levels on available energy. Be it industrial strength, private sector entrepreneurship or increased transportation services, developing societies require more energy to pursue their competitive and comparative advantages.

Hydroelectric power is generated from the River Nile at the Aswan High Dam, and remains to be the main source of renewable energy in Egypt. In the 1980s, the High Dam

---

[27] Clarkson, Richard, Kathryn Deyes. "*Estimating the Social Cost of Carbon Emission*". GES Working Paper 140. Available at www.hm-treasury.gov.uk.
[28] U.S. Department of Energy, www.eia.doe.gov/emeu/cabs/carbonemiss/chapter5.html
[29] U.S. Department of Energy, Ibid.
[30] De Moor, Andre and Peter Calamai, "Subsidizing Unsustainable Development" : www.ecouncil.ac.cr/econ/sud/chap4.html

generated around 50% of electricity for Egypt. However this rate has decreased to around 20% over the last ten years, although the demand for energy has increased.[31]

What makes increases in domestic consumption of energy so dangerous in developing countries is the price subsidy that generally accompanies them. Higher sales of a commodity at lower than market price creates lost revenues and unrealistic perceptions of the cost of energy, which in turn affects consumption behaviour. Currently in Egypt, production of energy resources is lagging due to a gradual transition to natural gas and an increasingly outdated oil economy.

Aside from hydroelectricity, Egypt should be boosting its use of other renewable energy resources such as solar and wind. The government in collaboration with USAID is undertaking a combined natural gas and solar power plant in Egypt. The proposed plant, which is funded by USAID and the Global Environmental Facility, would use solar energy during the day and natural gas at night, and is expected to start production in 2007. A few, small-scale solar projects under the patronage of UNDP Small Grants Program were also implemented to bring electricity to some rural areas in Upper Egypt. These projects, although limited and small in size, have contributed to a great improvement in the quality of life of the rural population. With respect to wind power, Egypt's New and Renewable Energy Authority is actively involved with the Danish and German governments to establish a large-scale wind project on the Red Sea Coast.[32]

In view of the current issues and potential conflict on water supply between the 10 countries on the River Nile, emphasis should be directed towards solar and wind more than hydro. Renewable resource technology in solar and wind is still making a shy entry into mainstream energy production in Egypt because the initial costs of importing the technology are high. However international aid for renewable resource technology is on the rise and may assist in producing sufficient energy to sustain required growth rates.

---

[31] U.S. Energy Information Administration, *Country Analysis Briefs, Egypt: Environmental Issues*.
[32] Ibid.

The Egyptian government cannot undertake the overall development process by itself and is in dire need of private investment, both domestic and foreign. The government has recently realized that requirement as necessary and not just politically desirable, and has already embarked on the path of re-organization as manifest in its serious privatisation efforts, provision of investment incentives, new tax law, in the hopeful pursuit for the creation of an environment conducive to investment. However, hidden transaction costs and dramatic irregular lead-times for bureaucratic approvals are still persistent.

Furthermore, Egypt currently has a comparative advantage in natural gas represented in its substantial natural gas reserves. It should therefore strive to enhance this advantage in order to establish a competitive advantage and position itself as a major player in the region through increased investments in the gas sector. However, since Egypt is not a supplier of high technology, its competitive advantage must be on the cost side. Achieving significant reductions in unit production costs for natural gas will gear Egypt towards what has been known as "Stein's competitive advantage", and such cost-reducing strategies must come from within, i.e. using local innovation and not borrowed technologies.

The launching of the Egypt-Jordan export pipeline is a positive step in the right direction for natural gas exports. The foreign exchange earnings from the proposed exports would improve Egypt's balance of payments' situation, aid it in servicing its debts and provide it with necessary funds to be re-channelled for investment in this strategic sector. The increased investments would inevitably create more job opportunities, which in turn would have a favourable effect on Egypt's current unemployment problem.

The above strategies for sustainable development in Egypt’s oil and gas sector are by no means easily attainable. For example, the gradual withdrawal of subsidies is considered a thorny issue, while attracting sufficient private and foreign investments is a major challenge. Shifting from oil to gas as a strategic resource will depend on the mindset of decision makers and must be complemented by political will, with Egypt's diplomatic relationship with many countries in the region a good advantage for a regional natural gas network. Adopting renewable technology, such as solar energy, must be accompanied by a cultural shift of the upcoming generations, away from social resistance to change and towards a risk-accepting future for social change.

It should be strongly emphasized that the most important underlying factor of development is the ultimate welfare of the Egyptian people. And while some development strategies may in the short run initially create inequality and differentials, in the long run, adherence and commitment to the vision would ensure higher levels of welfare across the social spectrum. The proposed strategies in this research target such an objective. The author believes that implementing on the proposed strategies and their accompanying schedules for oil and gas resource allocation should provide a turning point to long-term sustainable growth and development of the strategic oil and gas sector, and subsequently the rest of the Egyptian economy.

8. CONCLUSION:

The central theme in this research has been the analysis and forecast of Egypt's energy resources, regarding consumption, production, and exports/imports, for both oil and natural gas, with proposed strategies for sustainable development. The efficient utilization of energy resources in Egypt requires a major policy shift from oil historically regarded as the country's strategic energy resource, to a future in which natural gas will replace oil as the nation's strategic energy resource for decades to come.

On the international front, the oil market contains a prevailing cartel (OPEC) and has a non-differentiated price element across geographic regions, whereas the natural gas market contains a price advantage within regions, less thermal efficiency, and cleaner carbon emissions than oil. Those market characteristics are expected to remain unchanged in the future. Although it is forecasted that world energy demand will increase substantially, it is also expected that world energy supply will expand and overcome such demand, with high expected price variations for oil and lower price variations for natural gas.

On the domestic energy front, the energy sector in Egypt will remain a high priority sector and a strategic resource for the country's future. Historically, oil has been more price inelastic than natural gas, whereas natural gas has higher income elasticity. Oil production is declining due to X-inefficiency, and is expected to decline to 400,000 barrels per day in 2025. Egypt is expected to be a net importer of oil in the very near term as early as 2007. Oil consumption, on the other hand, will be increasing at 1.8% per year through 2025, and the removal of oil subsidies, when undertaken in phases, will not have a substantial effect on domestic oil consumption. On the other hand, with respect to natural gas, new gas reserves will see an increasing production growth trend of 10% per year, with the proven 66 trillion cubic feet of gas reserves expected to fully deplete by 2020, including sizeable export proceeds. However, oil producers will continue to generate comfortable profit margins at 70% while natural gas producers will generate 20% profit margins conditional on economies of scale but will have the potential to achieve Stein's competitive advantage by cost-reducing strategies. Large investment costs are required for natural gas production, and it is estimated that a $12 billion per year investment package over the next ten years (2006-2016) is required for natural gas production, in order to achieve an overall energy growth rate of 3% per year, with the economy having a 6% sustainable growth target.

Detailed strategies for Egypt's energy sector have been proposed, accompanied by their expected impact and economic requirements, summarized as follows:

(1) Policy shift from oil to gas as the strategic resource.
(2) Reduction/removal of oil subsidy.
(3) Adoption of renewable resource technology.
(4) Attract local and foreign investors (investment requirements).

These proposed strategies target long term welfare for the Egyptian economy.

APPENDIX

Optimal Resource Extraction Model:

The following model was utilized as part of the analysis undertaken in this paper:

Let $x(t)$ be the stock (reserves) of resource at time t,

$u(t)$ the quantity (production rate) extracted at time t,

$P(t)$ the price path of the resource,

and r is the discount rate.

It is logical to have the following equation of motion for $x(t)$:

$$\frac{dx(t)}{dt} = \dot{x} = -u(t)$$

In other words, the stock (reserves) declines at every time t by the amount of extraction (production).

Assuming extraction costs given by $C(u(t), x(t))$ with $C'(u) > 0$, $C_x \le 0$, and $C''(u) < 0$, such that extraction costs are an increasing function of production flow rate, but such an increase is diminishing with quantity, and including a "stock effect" $C_x \le 0$ (unit extraction costs are lower for reserves having the potential of economies for scale), the dynamic extraction path will be given by maximizing net benefits over time:

$$Max\{u(t), T\} \in \int_{t=0}^{T} e^{-rt}\left[P(t)u(t) - C(u(t), x(t))\right]dt$$

$$\dot{x}(t) = -u(t) \quad \forall t$$

$$u(t) \ge 0 \quad \forall t$$

$$x(0) = x_0 = \overline{R}$$

$x(T) \geq 0$

$u(t) = D(P(t))$.

Using the current value Hamiltonian (optimal control problem) yields:

$$H_c = P(t)u(t) - C(D(P(t)), x(t)) - m(t)u(t)$$

where $m(t)$ is the current value multiplier,

with $m(t) = e^{rt}\lambda(t)$,

where $\lambda(t)$ is the standard Lagrangian multiplier.

This optimal control problem is then solved by:

$\frac{\partial H_c}{\partial u(t)} = P(\bullet) + P'(\bullet)u(t) - m(t) = 0$	(1)	Sustainability Constraint
$\dot{m} - rm(t) = -\frac{\partial H_c}{\partial x(t)} = 0$	(2)	Equation of Motion
$\dot{x}(t) = \frac{\partial H_c}{\partial m(t)} = -u(t)$	(3)	Resource Depletion
$\lambda(T) = 0$	(4)	Transversality (terminal cycle) Condition

This gives rise to the following solution(s):

(a) When there is no stock effect, $C_x = 0$:

$$\dot{u} = D'(\bullet)\dot{P} = \frac{\dot{m}}{1/D'(P(t)) - C_{uu}}$$

(b) When there is a stock effect, $C_x < 0$:

$$\dot{u} = \frac{\dot{P} - \dot{m} - C_{ux}\dot{x}}{C_{uu}}$$

(c) When there are external costs, $e(t) > 0$:

$$\dot{u} = \frac{rP - rC_u}{1/D'(P(t)) - C_{uu}} - \frac{e(t)\left[r - \dot{e}/e(t)\right]}{1/D'(P(t)) - C_{uu}}$$

This paper, in solving for the optimal extraction rate, have assumed no stock effects, and did not account for valuation of externalities (external costs in production were not accounted for). The author recommends extension of his results to incorporate stock effects and externality valuations, but this is beyond the scope of this research.

Elasticity of Substitution between Oil and Natural Gas in Egypt:

One of the most common measures of the economy's energy substitution possibilities is the elasticity of substitution (σ). The elasticity of substitution defines the relative change in input proportions (in this case, we talk about oil and natural gas) in response to a relative change in their prices. In general, it is possible that the elasticity of substitution to vary; however, it is convenient to assume that elasticity of substitution is constant with time as it is assumed in this paper (LeBel, 1982, p.293; Nicholson, 2002, p.279). The elasticity of substitution between oil and gas in Egypt is calculated for both the production and consumption side using the following model:

$$\ln\left(\frac{Q_{OIL}}{Q_{NG}}\right) = \alpha + \sigma \ln\left(\frac{P_{NG}}{P_{OIL}}\right) + \varepsilon$$

where, Q_{OIL}= quantity of oil production or consumption (barrels of oil equivalent).

Q_{NG}= quantity of natural gas production or consumption (barrels of oil equivalent).

P_{OIL}= price of oil (US$ per barrel).

P_{NG}= price of natural gas (US$ per barrel).

σ = elasticity of substitution between oil and gas.

The value of σ is always positive, as the oil-gas ratio moves in the same direction as gas-oil price ratio. If σ is high ($\sigma \rightarrow \infty$), this means that oil and gas can be thought of as perfect substitutes for each other. On the other hand, if σ is very low (σ=0), this case shows that both oil and gas should be used in a fixed ratio regardless of the change in their price ratio. Running the above regression for Egypt for the period 1991-2003 for both production and consumption sides, it was found that the elasticity of substitution between oil and gas in production is 3.4; while the elasticity of substitution between oil and gas in consumption is 4.06.

The period from 1991 to 2003 witnessed an economic growth due to implementing the ERSAP in Egypt from 1991. However, such economic growth has slowed down. For expecting the growth of energy demand as a whole or growth of oil and natural gas consumption separately, Energy/GDP elasticity of 0.5 was calculated covering the period 1991-2003. This shows that when the Egyptian GDP grows at 1%, energy consumption would grow at 0.5%. Therefore, by applying an anticipated 6% rate of Egyptian economic growth, it is expected that energy should grow by 3% per year. The Oil/GDP elasticity (sensitivity between oil production and GDP growth rate) was also calculated and found to be 0.3, while the Natural Gas/GDP elasticity was found to be 0.9. This indicates that for 1% GDP growth, oil would grow at 0.3% and natural gas at 0.9%. This shows that natural gas consumption is more related to general demand in the Egyptian economy. This can be attributed to the heavily dependence on natural gas residentially and commercially especially for the last decade.

Hartwick's Rule and the Sustainability Constraint:

Both oil and gas are exhaustible resources that are irreversible. That is, if they are consumed, such consumption cannot be reversed, and if they are not consumed, then there has been an opportunity lost of not consuming or exporting their value. In an influential paper in 1977, John Hartwick proposed a rule for ensuring sustainability (i.e. non-declining consumption through time), in the case where an economy made use of a non-renewable resource (such as oil or natural gas) in its economic process. Hartwick shows that, so long as the stock of capital does not decline over time, non-declining consumption is also possible. Hartwick stated clearly what has come to be known as Hartwick's rule for this type of economy: "*if the accumulation of capital always exactly compensates in value for the resource depletion, then the level of consumption remains constant*" (Cairns et al., 2000, p.1; Hanley et al., 1997, p.426).

Hartwick argued that a sufficient condition to enjoy a constant consumption path is to invest in reproducible capital all the returns from the exhaustible resource use. This incorporates the discount rate (opportunity cost of time), and growth rate of consumption, indexed by uncertainty (relative risk). Using Hartwick's rule to get the social extraction rate to reach a sustainable consumption path for Egypt, we have to use the following formula:

$$r = \rho + \eta g$$

where, r is the social (optimal) extraction rate.

ρ is the social discount rate.

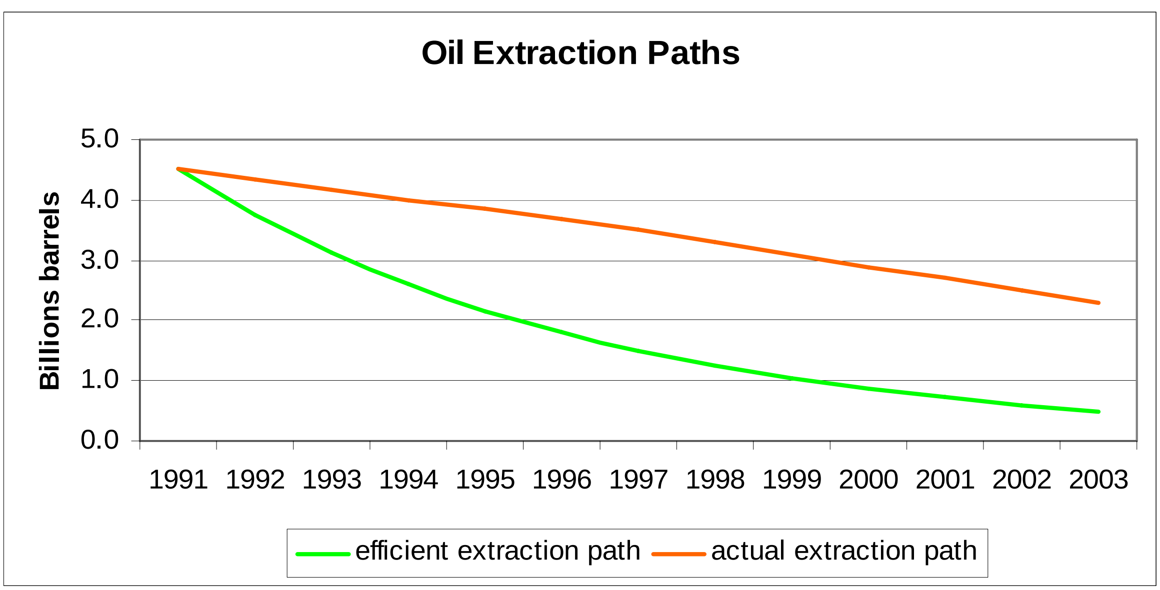
η is the coefficient of relative risk aversion.

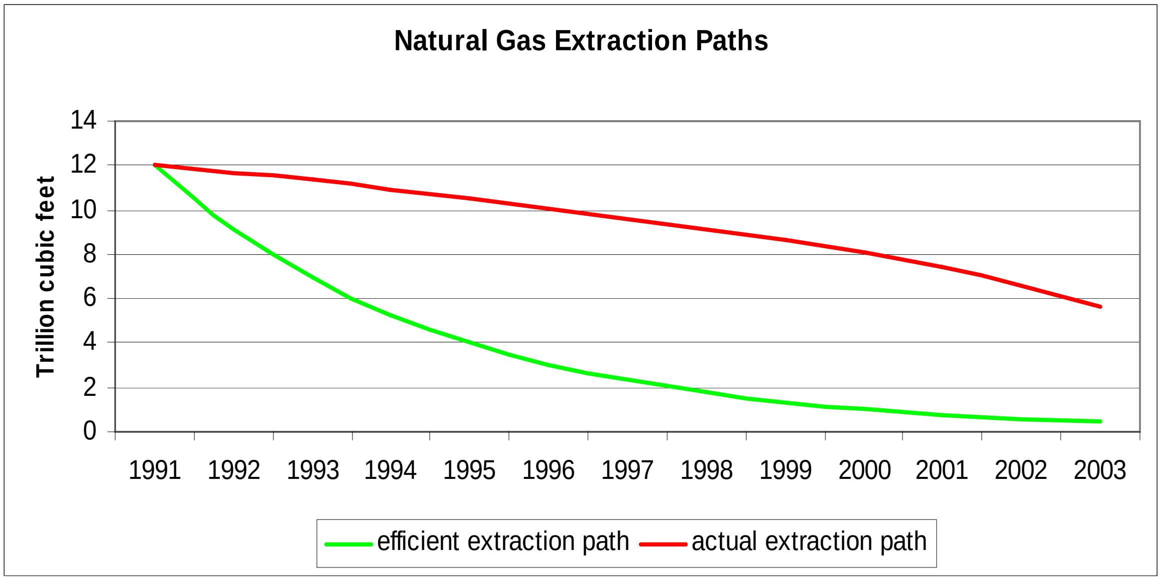
g is the growth of consumption of the exhaustible resource (oil or gas).

Historical Economic Extraction Paths for Oil and Natural Gas:

By applying the above formula to Egypt, and substituting for ρ=15% (historical social discount rate in Egypt), η=1 (assuming risk neutrality) and g_o= 1.8% (growth rate of consumption of oil in Egypt) and g_{ng}= 9% (growth rate of consumption of natural gas in Egypt); the economic extraction rate for oil and natural gas are 17% and 24% respectively. This result is acceptable in the way that the economic extraction rate for natural gas is greater than that of oil, which is a positive result. New discoveries of natural gas reserves in Egypt lead to an increase in consumption, which must reflect normally on its optimal extraction rate.

Optimal extraction rates of oil and natural gas in Egypt will be used to get the efficient extraction paths for both energy resources. The paper assumes oil and gas reserves in year 1991 to begin with as the initial time period (the start of the Transversality cycle) ; to derive the historical extraction paths, then, calculates for each resource an efficient and an actual extraction path.





It is observed for both resources that the actual path is higher than that of the efficient path showing that oil and gas have not been extracted efficiently in Egypt. Both resources have been under-extracted in the past. Hence, they show that Egypt have been actually extracting less than it should be, and that may be related to immaturity of some fields or to inefficient technology used, or due to inadequate or insufficient investments for resource extraction.

In addition, both historical resource graphs show that the actual path is decreasing with a decreasing rate while the efficient path is decreasing with an increasing rate, from which it can be concluded that both curves should intersect sometime in the future. By forecasting the resource path for oil (comparing the historical actual resource path to the forecasted efficient resource path), it was found that the two paths will intersect in 2015. As Egypt faces a decrease in oil reserves, it will slowly decrease (or increase in a decreasing rate) its oil extraction. On the other hand, the actual extraction path for gas is expected to decrease sharply due to high expected extraction of gas, as Egypt will depend totally on it for consumption and exporting due to its new reserves discoveries. Since gas is a new resource with large reserves still unutilized, actual and forecasted paths are identical.

However, an interesting exercise has been conducted whereby relative natural gas extraction paths were derived (extraction rates relative to a timeline of historical reserves). The actual flow rate of natural gas relative to historical reserves, when forecasted, is expected to converge to the efficient forecasted flow rate relative to the new reserves, by 2010. This indirectly means that Egypt must try to acquire advanced technologies related to natural gas production (including technologies for resource extraction and mining exploration) more intensely than acquiring advanced technologies for oil. In essence, the country's future energy needs will depend more on natural gas technology.

REFERENCES

AmCham (American Chamber of Commerce in Egypt) (2003), "The Petroleum Industry in Egypt: Investment & Prospects", *Business Studies & Analysis Center*,51p.

APRC (Arab Petroleum Research Center) (2003), "Egypt", *Arab Oil and Gas Directory*, Arab Petroleum Research Center, Paris, France, pp.85-120.

Bertelsmann: http://www.bertelsmann-transformation-index.de.

Cattan, Henry (1967). The Law of Oil Concessions in the Middle East and North Africa, Oceana Publications, Inc., Dobbs Ferry, New York, 1967.

Cairns, Robert and Zhao Yang (2002), "The Converse of Hartwick's rule and Uniqueness of The Sustainable Path", *Natural Resource Modelling*, Vol.13, No.5, pp.1-10.

CIA Online, World Fact Book: Egypt, http://www.cia.gov/cia/publications/factbook/geos/eg.html

Gallon, A. Rebecca *et al* (1993). Fundamentals of Oil and Gas Accounting, Pennwell Books, Tulsa, Oklahoma, Third Edition, 1993.

Clarkson, Richard and Kathryn Deyes (2002). "*Estimating the Social Cost of Carbon Emissions.*" Government Economic Service Working Paper No. 140, 2002. http://www.hm-treasury.gov.uk/media/209/60/SCC.pdf.

Colliti, Marcelo and Claudio Simeon (1996). Perspectives of Oil and Gas: the Road to Interdependence, Kluwer Academic Publishers, London, 1996.

DeMoor, Andre and Peter Calamai (2005). Subsidizing Unsustainable Development: Undermining the Earth with Public Funds. http://www.ecouncil.ac.cr/econ/sud/chap4.htm.

Egypt State Information Service, Energy Outlook on Egypt.

EIA (Energy Information Administration) (2005), *Country Analysis Briefs: Egypt*, US Department of Energy, Washington, DC.

EIA (Energy Information Administration) (2004), *International Energy Outlook 2004*, US Department of Energy, Washington, DC.

Hartwick, John M. (1977), "Intergeneration Equity and the Investing of Rents from Exhaustible Resources", *The American Economic Review*, Vol.67, No.5, pp.972-974.

Hanley, Nick, Jason F. Shogren and Ben White (1997), *Environmental Economics: In Theory and Practice*, Oxford University Press, Oxford.

LeBel, Philip G. (1982), *Energy Economics and Technology*, The Johns Hopkins University Press, Baltimore.

Middle East Economic Digest, Egypt: *Petrochemicals*, January 2003.

Ministry of Petroleum of Egypt: http://www.emp.gov.eg/ENGLISH/history.html.

Nicholson, Walter (2002), *Microeconomic Theory: Basic Principles and Extensions*, Thomson Learning Inc., The USA.

Oil and Gas Journal (numerous issues), including: "Worldwide Look at Reserves and Production", *Oil and Gas Journal*, Vol. 103, December 2005

OFE (Office of Fossil Energy) (2001). "An Energy Overview of the Republic of Egypt", *Energy Overview*, Office of Fossil Energy, Washington, DC.

Seda, Rodrigo (2005). *"Apache Egypt's Contribution to the Egyptian National Economy"*, The American University in Cairo, 2005.

UNDP Egypt: http://www.undp.org/Egypt.

U.S. Department of Commerce, Country Commercial Guide FY2002: Egypt www.world-digest.com/Guides/eg

U.S. Department of Energy, Energy Information Administration, *Country Analysis: Egypt* www.eia.gov/emeu/cabs/egypenv.html.

US Department of Energy (DOE), International Energy Outlook, U.S. Energy Information Administration, www.eia.doe.gov/emeu/cabs/carbonemiss/chapter5.html.

U.S. Department of Energy, Energy Information Administration, *World Energy Use and Carbon Dioxide Emissions, 1980-2001*. http://www.eia.doe.gov/emeu/cabs/carbonemiss/energycarbon2004.pdf.

World Bank, http://www.worldbank.org/Egypt/ElectricityandRenewables.

World Bank, www.worldbank.org/data/dataquery/html.

World Energy Council, Energy in Egypt, 2002 www.worldenergy.org/wec-geis/wec-info/structure-organisation/ea/cairo/stats/eie.asp.

ACKNOWLEDGEMENTS

The author would like to thank Dr. Hanaa Kheir El Din for help and encouragement during the time spent in writing this research. Helpful information and thanks also go to Professor Robert Mabro and Professor John Salevurakis. In this paper, substantial research assistance was provided by Mr. Amr Al Garhi, MA in Economics, The American University in Cairo. Additional research assistance provided by Homa Azargoshasb, Abdula Mutualo, and Loubna Olama, MA Candidates in Economics, The American University in Cairo. The author would like to thank them all for valuable assistance.