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Nuclear Power in Saudi Arabia, Egypt, and Turkey – how cost effective?

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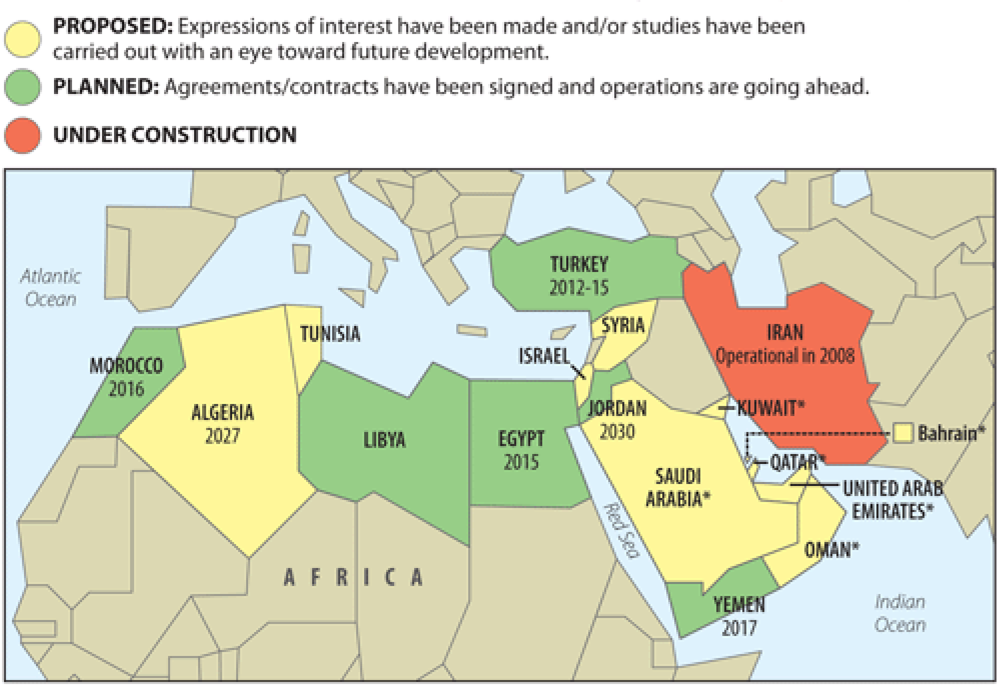
INTRODUCTION

The interest in nuclear energy in the Middle East and North Africa has become widespread in recent years. Although most attention has been focused on the progress of Iran in its nuclear program, six other countries in the region have signed agreements to proceed with nuclear power development and another ten have expressed interest or conducted studies related to nuclear power.[1]

Figure 1. Interest in Nuclear Power in the Middle East and North Africa



Source: Christian Science Monitor, November 1, 2007.

[1] Murphy, Dan. "Middle East racing to nuclear power," Christian Science Monitor, November 1, 2007.

Speculation on the motivation for this interest in nuclear energy incorporates both political and economic rationales. Politically, the arguments focus on the regional rivals of those states now seeking nuclear power. Observers have argued that Shi'ite Iran's nuclear push has instigated the growing interest among Sunni states.[2] As Iran's nuclear program strengthens despite international pressures, Sunni interest in nuclear alternatives may concurrently intensify. Other political arguments point to Israel as a chief reason for further Middle Eastern nuclear development,[3] with its lack of participation in nonproliferation treaties.

In addition to these political rationales for nuclear development, official sources more often focus on economic arguments for nuclear power. These include dwindling oil reserves, a lack of natural resources, or lucrative export opportunities when natural gas prices are high. Officials further emphasize the growth of many Middle Eastern states, such as the United Arab Emirates which "argues that it needs nuclear energy to satisfy soaring demand for power and desalinated water."[4] Even analyses provided to senior U.S. policymakers acknowledge the political impetus for seeking nuclear power generation but, as in the case of Saudi Arabia, "this is not to suggest the Saudis do not have an energy-based argument for their interest in nuclear energy. According to the U.S. Energy Information Administration, Saudi Arabia's Water and Electricity Ministry (WEM) predicts that the country's electricity demand will double by the years 2023–25."[5]

This analysis focuses on evaluating the economic and resource arguments for the development of nuclear power that are oft cited with three case studies: Saudi Arabia, Egypt, and Turkey. These three case studies were selected for having unique characteristics but also being representative of other countries with interest in nuclear power. Saudi Arabia has large fossil fuel reserves which form the base for its economy, maintains a strong sovereign credit rating, and has fast rising electricity demand which is partly driven by desalination needs. Comparable countries to Saudi Arabia include Libya and the United Arab Emirates. Egypt is more comparable to Algeria, Morocco, Tunisia, and Yemen, having some domestic fossil fuel reserves but a poor credit rating. Finally, Turkey represents a fairly unique case study with no domestic fossil fuel reserve and a strong economy based on non-oil/gas sectors. By reviewing and analyzing three very different case studies, this analysis seeks to shed light on the broader applicability of nuclear power in the region.

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[2] Christian Science Monitor, November 1, 2007. "To have 13 states in the region say they're interested in nuclear power over the course of a year certainly catches the eye," says Mark Fitzpatrick, a former senior nonproliferation official in the US State Department who is now a fellow at the International Institute for Strategic Studies in London. "The Iranian angle is the reason."

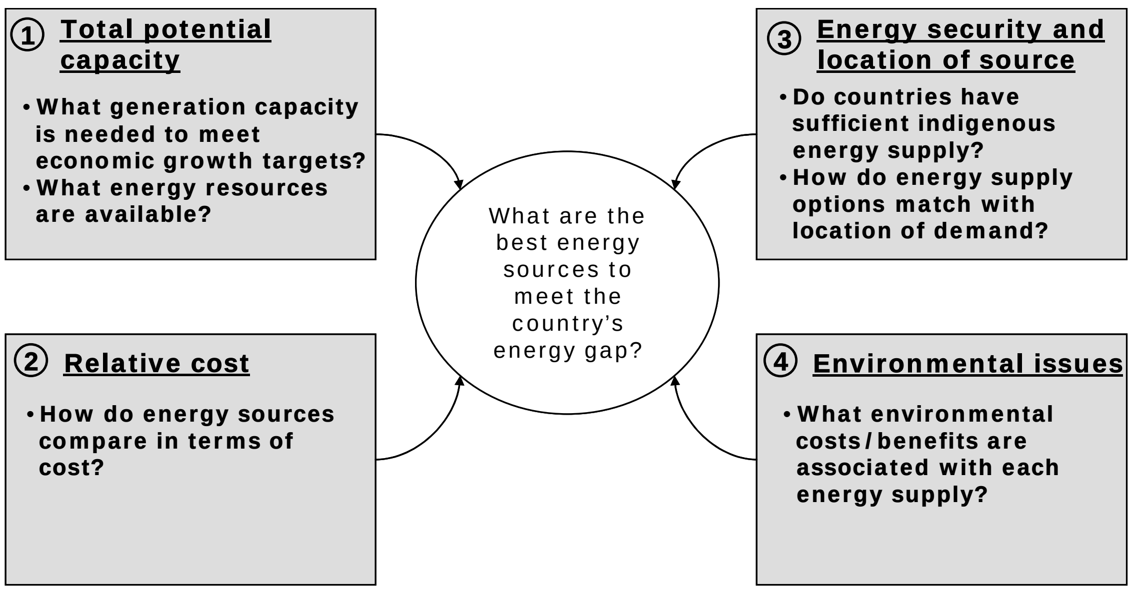
[3] Christian Science Monitor, November 1, 2007. "They feel politically threatened by Iran's nuclear program, they've pointed out rightly that Israel [hasn't been] a member of [nonproliferation] treaties for many years," says Jon Wolfsthal, a nonproliferation expert at the Center for Strategic and International Studies in Washington."

[4] Financial Times, January 21, 2008.

[5] "Chain Reaction: Avoiding a Nuclear Arms Race in the Middle East," Report to the Committee on Foreign Relations, United States Senate, February 2008, Page 15. Available at: http://www.cfr.org/content/publications/attachments/BradleyBowman.pdf.

In evaluating the economic and resources arguments for nuclear power, this analytical framework takes into account four key components to determine the best energy sources for meeting a countries future energy gap – (1) total potential capacity, (2) relative cost, (3) energy security and location of sources, and (4) environmental issues.

Figure 2. Analytical framework

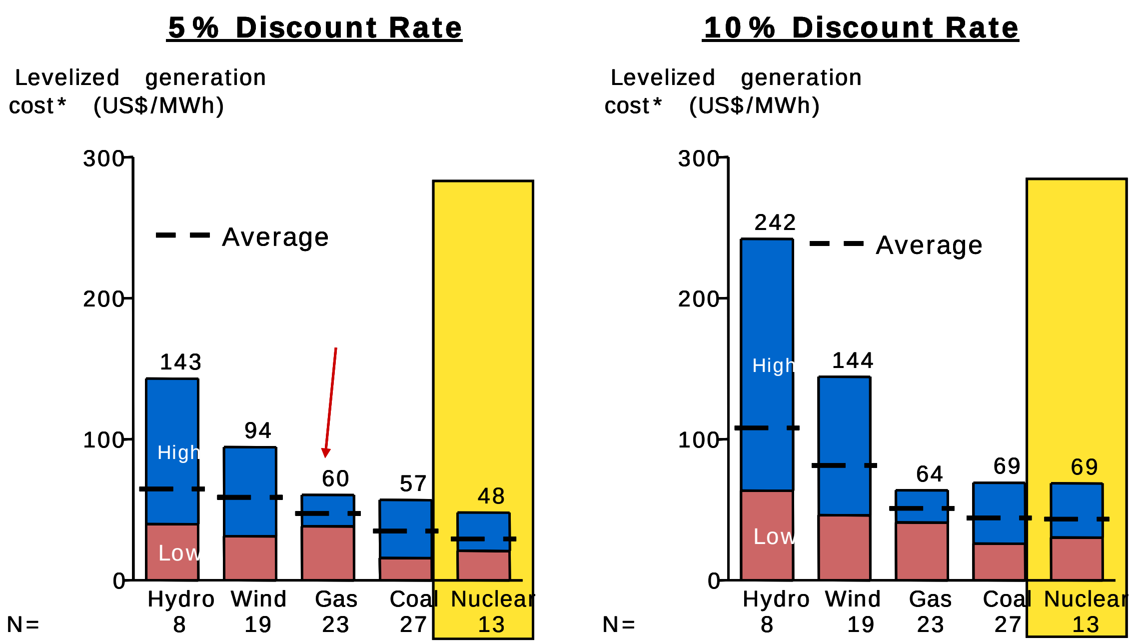


Total Potential Capacity. This analysis seeks to answer two key questions, namely (i) what generation capacity is needed to meet economic growth targets and (ii) what energy resources are available? This factor varies widely by country. In most cases a combination of energy sources, rather than a single technology, would be required to meet future demand growth and to cover both the peak and base load demands.

Relative Cost. The development of generation capacity needs to take into account the relative costs across a variety of generation options. While relative cost should not be the only selection criteria due to the risk mitigation benefits of having a more balanced national energy portfolio, they play a crucial role in determining the commercial viability and development of generation capacity. Though country specific-factors can impact relative cost comparisons, it is useful to understand structural factors that affect relative cost.

Although gas, coal, and nuclear are the lowest cost options according to global surveys, the discount rate plays a critical role in determining overall cost effectiveness. With the large upfront capital costs of nuclear generation development and the relatively low cost of fuel on a per kilowatt hour basis, the discount rate plays a critical role in determining the relative costs across these options. At a 5% discount rate the levelized cost of nuclear is US$29 / megawatt hour compared with $47 for natural gas. But at a 10% discount rate, nuclear generation costs $43 / megawatt hour compared with $51 for natural gas (see Figure 3). The implication is that in countries with higher cost of capital, as is the case with most developing countries, the cost advantage of nuclear power declines. Discount rates influence every infrastructure project and may range from 8-15%. Furthermore, moving beyond the high-level global survey, it is important to broaden the factors being considered.

Figure 3. Global Survey of comparative costs



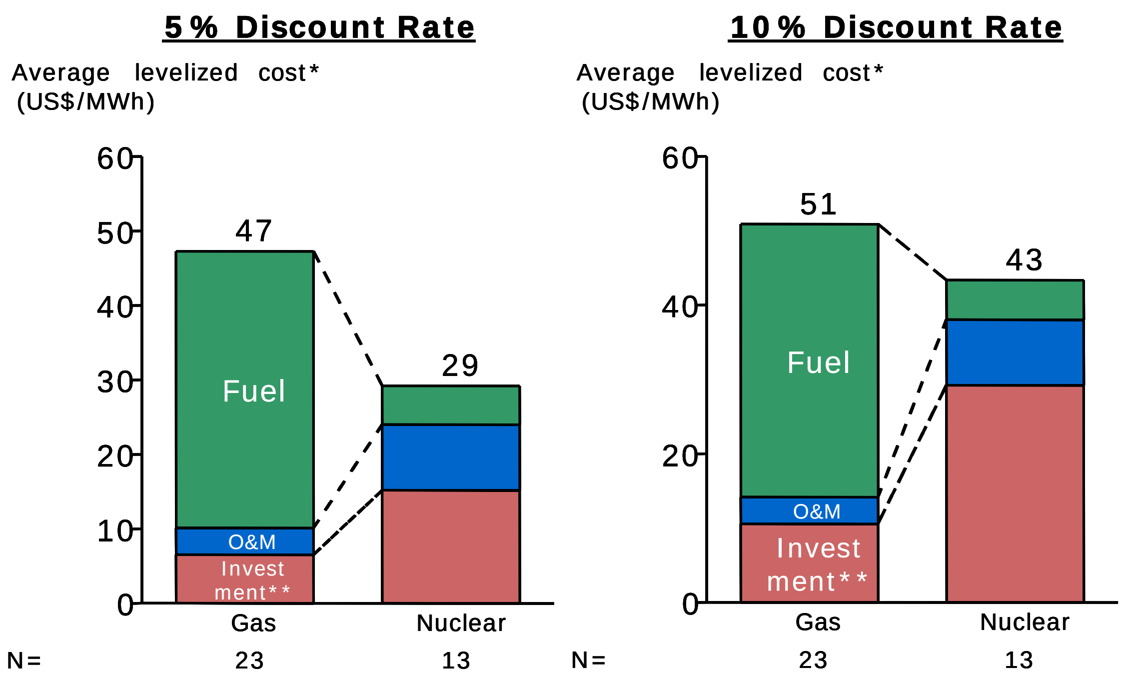
*Sources and notes: *Data from survey of new facilities in 21 countries, mostly OECD but also include 4 developing countries. Levelized generation cost include initial Investment cost, Operation and Maintenance cost, Fuel cost, and in the case of nuclear, decommission cost; main assumptions – 85% capacity factor for plants, 40 year lifetime for coal and nuclear plants, for other plants lifetime come from country level responses, fuel price projection based on each country's models. "Projected Cost of Generating Electricity 2005 Update" – Nuclear Energy Agency / International Energy Agency*

The global survey of cost comparisons ignores a number of factors, and in doing so underestimates the relative cost of nuclear generation. First, the 45 global benchmarks of nuclear generation costs reflect vendor numbers which many experts believe to be too low.[6] Second, nuclear power plants generate significant amounts of electricity in a more centralized manner, requiring extensive transmission and distribution networks. Not only does this require additional investment, but also results in higher amounts of energy loss, as even best-in-class networks incur a ~20% system loss of electricity. Third, cost items which are not directly borne by the power plant operator,

[6] Based on expert comments during the Nonproliferation Policy Education Center Conference, Prague, Czech Republic, 18 March 2008.

such as the cost of a robust government regulatory body, the cost and time to build up human capital to operate the plants, and the cost of insurance and loan guarantees, are much higher for nuclear power plants versus other resources and are not included in the calculations. Taken together, real cost of nuclear power plants may be significantly higher than the costs reflected in the IEA survey. While some analysts estimate low costs for new plants, such as the EIA, University of Chicago, and vendors with estimates of $1,500-$2,100 per kilowatt, other analysts, such as Keystone Center, Standard & Poor's, and Moody's estimate a much higher range from $3,600-$6,000 per kilowatt.[7]

Figure 4. Cost comparison of natural gas and nuclear generation



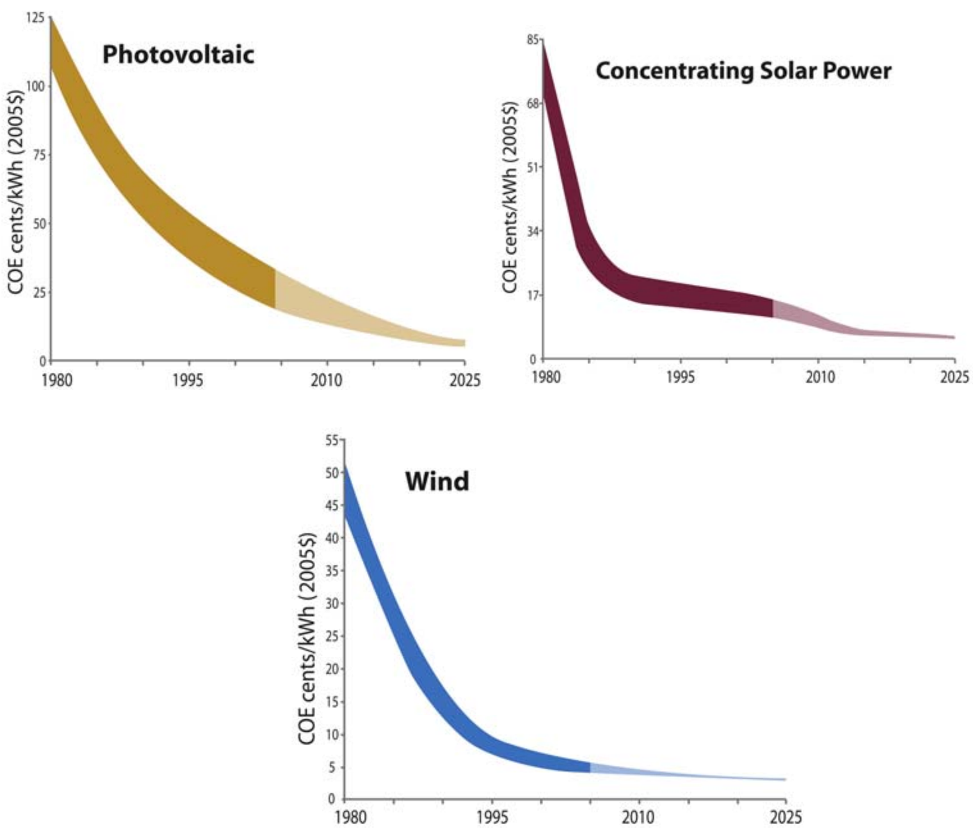
*Notes and sources: *Average of data from survey of new facilities in 21 countries, mostly OECD but also include 4 developing countries. Levelized generation cost include initial investment cost, Operation and Maintenance cost, Fuel cost, and in the case of nuclear; main assumptions – 85% capacity factor for plants, 40 year lifetime for coal and nuclear plants, for other plants lifetime come from country level responses, fuel price projection based on each country's models. **Investment cost for nuclear power includes decommission cost Source: "Projected Cost of Generating Electricity 2005 Update" – Nuclear Energy Agency / International Energy Agency*

Also, a number of cost saving potentials exist for renewable sources such as hydro (particularly small hydro projects) and wind that are not taken into account here. First, renewable power generation can be decentralized and local, providing savings in transmission infrastructure. Second, most of the renewable technologies are still in the process of development, with cost decreasing over time due to both increase in scale and

[7] Jim Harding. "Reactor Economics in a Carbon Constrained World," November 2007. Available at: http://www.npec-web.org/Presentations/DRAFT-20071105-Harding-ReactorEconomics.pdf.

advancement in technology (see Figure 5). Third, in a potential regime where there is a carbon tax, renewable sources have the advantage of zero emission. Lastly, even though per unit cost of electricity from renewable sources may be higher, renewable projects require much less upfront capital due to smaller sizes of the generators and can be brought on-line incrementally. This is an advantage particularly if the cost of capital is high, and when energy demand growth in a particular area is uncertain and thus a more modular expansion of generation capacity is desirable.

Figure 5. Cost Curve for Solar Photovoltaic, Concentrating Solar Power, and Wind, 1980-2025[8]

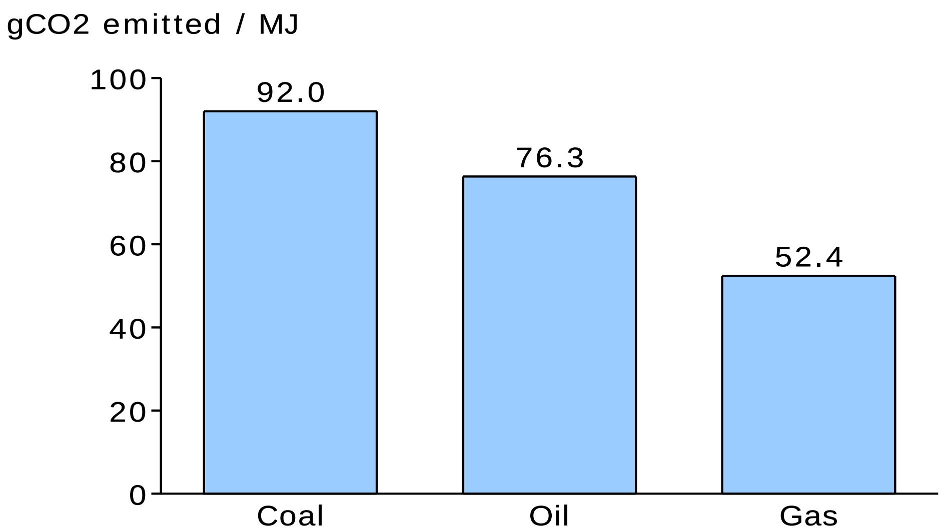


Energy security and location of source. This component seeks to address the questions about (i) whether countries have sufficient indigenous energy supply sources and (ii) how energy supply options match with local demand. Where countries depend on imports to satisfy energy demand, developing indigenous sources of power, such as nuclear or renewable energy, makes more sense. In cases where the natural endowment of energy sources is located far from the population centers that require that energy, alternatives also have to be considered.

[8] US National Renewable Energy Laboratory.

Environmental issues. Finally, environmental issues are assessed to determine what the environmental costs and benefits are with each of the supply options. Hydrocarbon based resources emit a variety of pollutants, including SO_2 that contributes to acid rains and CO_2 which impacts global climate change. However, within the hydrocarbon family, there is a large difference in environmental impact, with natural gas being much cleaner than oil, than coal. Though nuclear power does not emit CO_2 or SO_2, it does pose potential threats to the environment in the form of accidents and waste disposal. Renewable sources tend to have the best environmental record, although large hydropower projects can also adversely affect nearby ecosystems.

Figure 6. Comparison of CO_2 emissions across fossil fuel resources

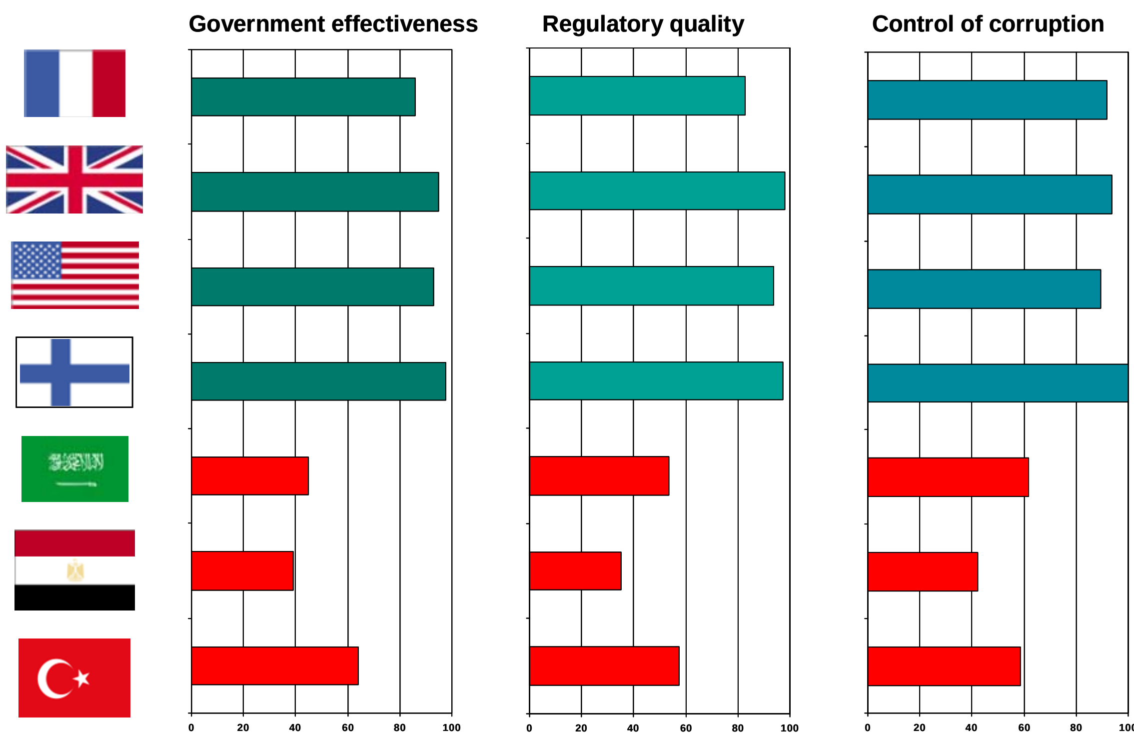


Notes and sources: Source: Intergovernmental Panel on Climate Change, "Working Group III Fourth Assessment Report", Chapter 4: Energy Supply,

Viability. An evaluation of governance indicators also highlights important points about the ease (and difficulties) of implementing a policy to develop nuclear power. The successful development and operation of nuclear plants in countries such as France, Great Britain, the United States, and Finland have all occurred in countries with relatively strong governance and regulatory effectiveness. But despite strong governance, many projects in France, Great Britain, the United States, and Finland have not been completed on-time, have unclear commercial viability, have required significant government subsidies and bailouts, or have encountered other problems. This suggests that even with relatively high marks in terms of government effectiveness, regulatory quality, and the control of corruption (see Figure 7), nuclear power development is inherently difficult to coordinate between the private and public sectors.

By comparison, Saudi Arabia, Egypt, and Turkey have considerably lower scores across government effectiveness, regulatory quality, and control of corruption, as rated by the World Bank governance indicators which serve as a general measure of governance. Each of these dimensions could have considerable implications on the likelihood and effectiveness of nuclear development in these countries. Given the strong role of government in the subsidization of nuclear power in other countries, weaker government effectiveness could reduce the viability of even subsidized projects. Nuclear power also has significant regulatory requirements for safe operations and handling of nuclear materials and waste. Weak regulatory systems would be particularly vulnerable in dealing with nuclear issues. Finally, nuclear power development requires huge upfront construction costs. Large scale infrastructure projects are notoriously prone to corruption which can both substantially increase the costs of these projects as well as deteriorate the safety standards of completed projects. These real "ancillary costs," often not considered or factored in, can have important consequences. Increased costs due to corruption will make nuclear power relatively less attractive in these countries while deteriorated safety standards could have catastrophic consequences.

Figure 7. World Bank Governance indicator comparison



Source: World Bank governance indicators, 2007. ***http://info.worldbank.org/governance/wgi/index.asp***

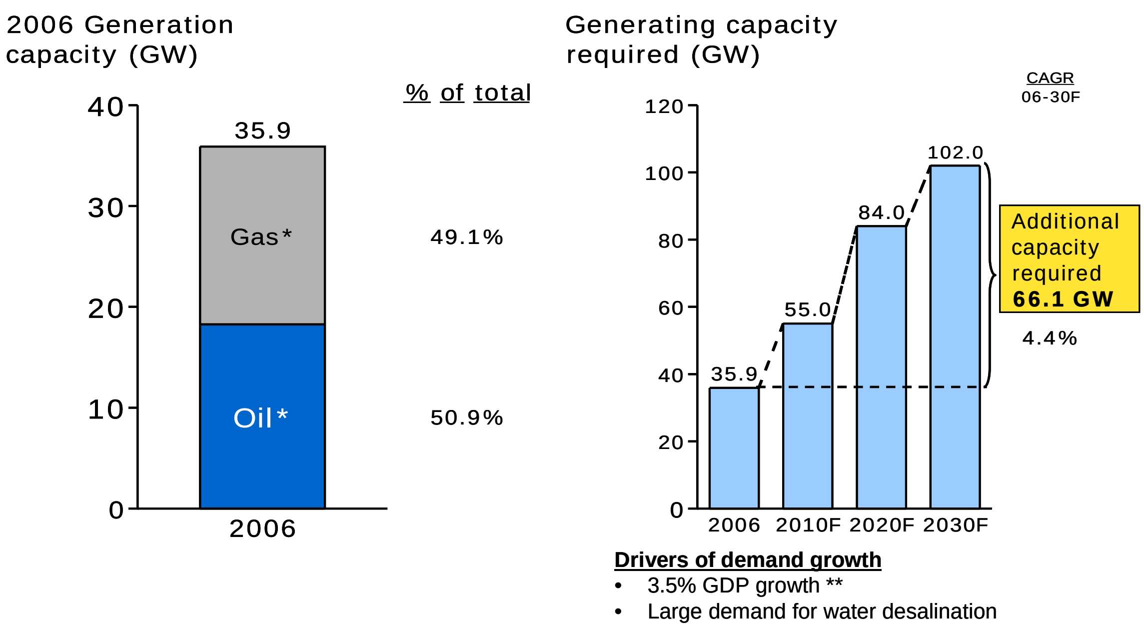
The specific energy situations for Saudi Arabia, Egypt, and Turkey will now be addressed in light of the issue of whether nuclear power is necessary to meet their electricity generation needs.

SAUDI ARABIA

Total potential capacity

Energy demand in Saudi Arabia is expected to grow relatively rapidly in the next 25 years. Based on estimations of 3.5% GDP growth, it is expected that Saudi Arabia's generation capacity will need to grow at 4.4% necessitating an addition of 66.1 gigawatts of generation capacity by 2030.[9] Although current use is roughly 53% residential and 20% industrial, growth in electricity demand is expected to be largely driven by requirements of new desalination plants. Of the current 24 gigawatts planned for development in Saudi Arabia, 15GW are estimated to be for desalination needs.[10]

Figure 8. Saudi Arabia's current and projected generating capacity



*Notes and sources: *Gas and Oil generation capacity split based on 2005 proportions*
***GDP growth rate from 2003-2030. Saudi Arabia Electricity and Cogeneration Regulatory Authority Annual Report 2006; International Energy Agency Statistics; World Energy Outlook 2005 – International Energy Agency.*

Saudi Arabia's electricity generation capacity currently relies on fossil fuel resources despite having considerable renewable energy resources. With 35.9 gigawatts of total generation capacity, 50.9% is generated using oil and 49.1% uses natural gas.[11] The solar and wind resources available to Saudi Arabia remain largely untapped, with no signal from the national government to promote significant investment.

[9] Saudi Arabia Electricity and Cogeneration Regulatory Authority Annual Report 2006; International Energy Agency Statistics; World Energy Outlook 2005 – International Energy Agency.
[10] Saudi Arabia Electricity and Cogeneration Regulatory Authority Annual Report 2006.
[11] Saudi Arabia Electricity and Cogeneration Regulatory Authority Annual Report 2006; International Energy Agency Statistics; World Energy Outlook 2005 – International Energy Agency.

The development model for the power sector in Saudi Arabia is to shift more generation to gas powered turbines, especially in times of high oil prices, and use oil resources to fill the gap between supply and demand. In line with this strategy, almost all new power plants being built now can switch between the two fuels. According to International Energy Agency projections, by 2030, new oil generation capacity would likely total 22.7 gigawatts and new gas generation capacity would likely amount to 43.4 gigawatts. This would make natural gas the dominant generation source with 60% of the total capacity by 2030.[12] This strategy for developing new electricity generation has been emphasized by industry experts at ARAMCO, who have said that: "The Saudi government has not seriously considered electricity generation from any source other than gas, supplemented by crude oil. The abundance of the resource just means that there's less economic need for anything else."[13]

Relative cost

For natural gas generation, the primary cost component is the fuel, so the relative economics of generation options in Saudi Arabia must incorporate significantly lower natural gas prices. While natural gas prices in Western Europe, North America, and East Asia fluctuate between $6 and $8 per million BTUs, the costs are considerably lower in gas producing countries like Saudi Arabia where the cost is roughly $0.8 per million BTUs (see Figure 9). As a result, the relative costs between natural gas and nuclear generation are vastly different in Saudi Arabia, with nuclear costing $43 per megawatt hour and natural gas generation costing less than $20 per megawatt hour.

The question then arises about the opportunity cost of natural gas and the ability of Saudi Arabia to export it lucratively. Although more detailed analysis could yield the exact threshold whereby the opportunity cost is too great and natural gas should be exported instead of used for electricity generation, a rough approximation suggests that threshold has not yet occurred. First, natural gas prices would have to be high enough for the revenue generated from the sale to cover the cost of nuclear power in Saudi Arabia. To cover the costs of nuclear generation, current natural gas prices would have to increase by 18% for a break-even.[14] However, this estimation assumes that the costs of developing nuclear generation in Saudi Arabia would be the same as the world average, despite additional construction costs and a weaker government and regulatory effectiveness. Taking nuclear costs from more roughly comparable countries, the costs for nuclear could be as much as $58 per megawatt hour,[15] thereby requiring a roughly 41% increase in natural gas prices before meeting the threshold whereby exportation of natural gas makes sense in Saudi Arabia. An 18% increase in natural gas prices in Western Europe, North America, and East Asia would mean a cost per million BTUs of

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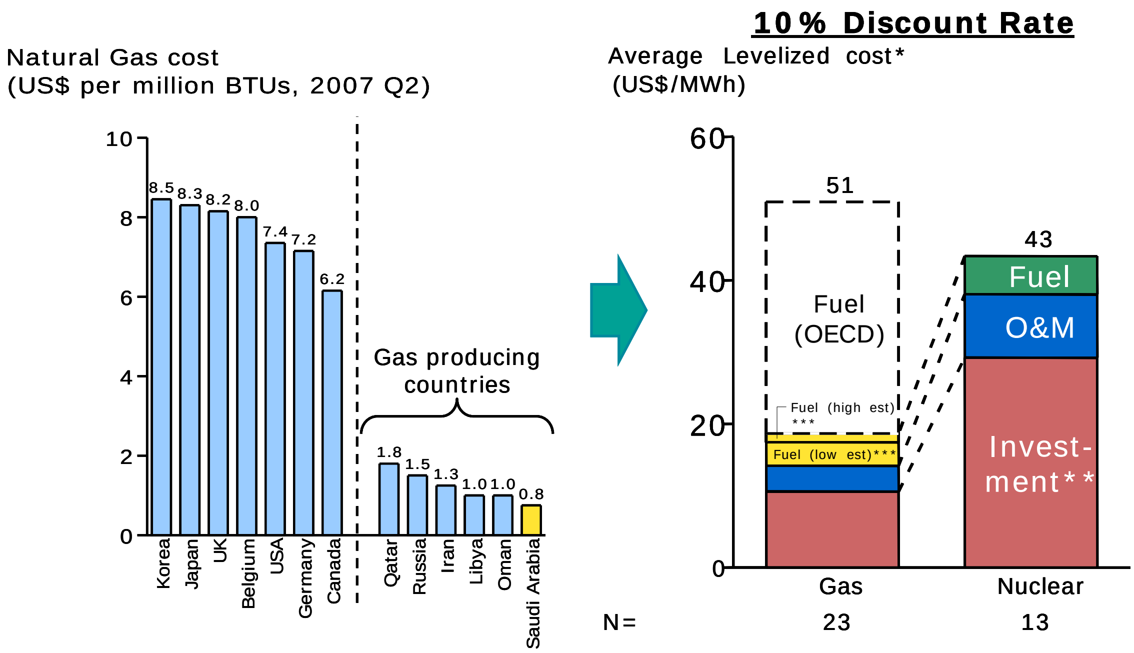
[12] Projection based on base case scenario in World Energy Outlook 2005, International Energy Agency Source: Saudi Arabia Electricity and Cogeneration Regulatory Authority Annual Report 2006.
[13] Telephone discussion with industry expert. February 2008.
[14] Dalberg analysis.
[15] Dalberg analysis.

$9 and a 41% increase would mean a cost of approximately $11 per million BTUs. For nuclear development and exportation of natural gas to make sense, prices would need to remain high. Recent decreases in price suggest that this threshold is even further away.

Figure 9. Natural gas costs and resulting cost comparison of natural gas and nuclear generation in Saudi Arabia



*Notes and sources: *Average of data from survey of new facilities in 21 countries, mostly OECD but also include 4 developing countries. Levelized generation cost include initial investment cost, Operation and Maintenance cost, Fuel cost, and in the case of nuclear; main assumptions – 85% capacity factor for plants, 40 year lifetime for coal and nuclear plants, for other plants lifetime come from country level responses, fuel price projection based on each country's models. **Investment cost for nuclear power includes decommission cost. ***calculated as Saudi's gas price as % of the lowest and highest price in the OECD gas price data available. Source: American Chemistry council; "Projected Cost of Generating Electricity 2005 Update" – Nuclear Energy Agency / IEA*

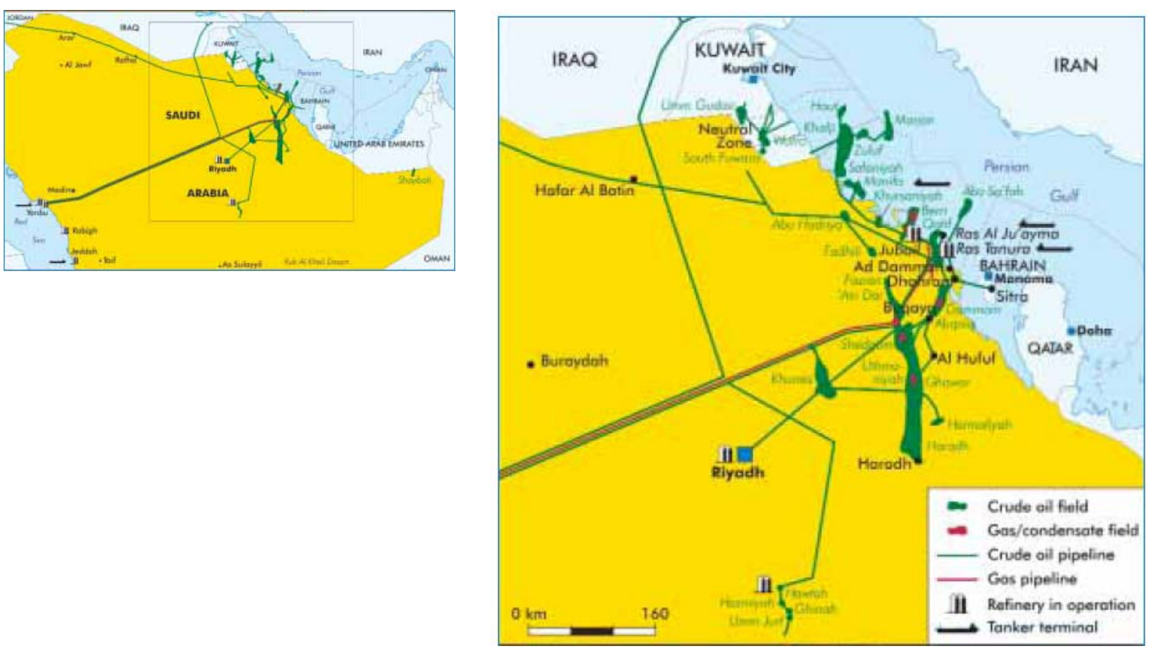
Second, an assessment should take into account the additional costs incurred by building infrastructure for natural gas exportation. This exportation could occur either via pipelines (which would require regional agreements between Saudi Arabia and its neighbors) or via liquefied natural gas tankers. Either case would require significant investments in infrastructure would put the threshold for lucrative exportation of natural gas even higher.

Energy security and location of energy source

Saudi Arabia has abundant reserve of natural gas to provide for its growing demand for electricity generation. Current reserves stand at ~240 trillion cubic feet, with a 2005 annual production level of 2.87 trillion cubic feet[16]. There have been recent shortages of natural gas in the domestic market, leading to incidents of electricity blackouts. The supply crunch occurred due to traditional practices of only producing associated gas (gas co-produced from oil wells). Recent change in government policy to limit gas flaring and encourage production from independent gas field should address the supply shortage[17]. Realizing that natural gas is important for the domestic electricity market, the government has stepped up exploration projects with the hopes of adding another 50 trillion cubic feet to reserves by 2016. It has also for now earmarked all natural gas for domestic consumption.

Natural gas supply within Saudi Arabia is transported by the Master Gas System. The Master Gas system came online in 1982 predominantly to transport associated gas from the Ghawar field, and since then have expanded as to transport gas from a variety of fields to industrial centers at Yanbu and along the Red Sea coast[18]. Saudi ARAMCO intends to build a further 3,000 km of gas pipeline by 2006 to expand the Master Gas system[19]. Continued investment will ensure meeting the demand of the rapidly expanding gas power sector.

Figure 10. Natural gas and oil infrastructure in Saudi Arabia



Source: World Energy Outlook 2005 – International Energy Agency

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[16] Energy Information Administration "Country Analysis Brief – Saudi Arabia", 2006
[17] International Energy Agency, "World Energy Outlook 2005 – Middle East"
[18] Ibid
[19] Ibid

Environmental Impacts

Environmental improvements from electricity production could result from proper development of Saudi's solar and wind resources. By contributing nearly half of the carbon emissions of coal-generation, the use of natural gas for electricity generation helps to keep Saudi Arabia's per capita emissions relatively low. However, the environment impact of Saudi Arabia's power sector could be further improved should the government move away from a policy of neglecting the country's renewable resources.

Conclusions

While Saudi Arabia will see an increase in the need for electricity, it has focused on developing natural gas generation to meet this growing need. In the foreseeable future, natural gas provides a cost competitive generation option vis-à-vis nuclear. The opportunity cost of natural gas exportation may not be high enough to induce Saudi Arabia to sell its natural gas and build nuclear power instead. Furthermore, Saudi Arabia has invested in its Master Gas System in order to leverage its natural gas resources for electricity generation. This strategy will likely have a positive environmental impact, though increased focus on renewable energy opportunities in terms of solar power and wind power could further improve Saudi Arabia's environmental impact.

EGYPT

Total Potential Capacity

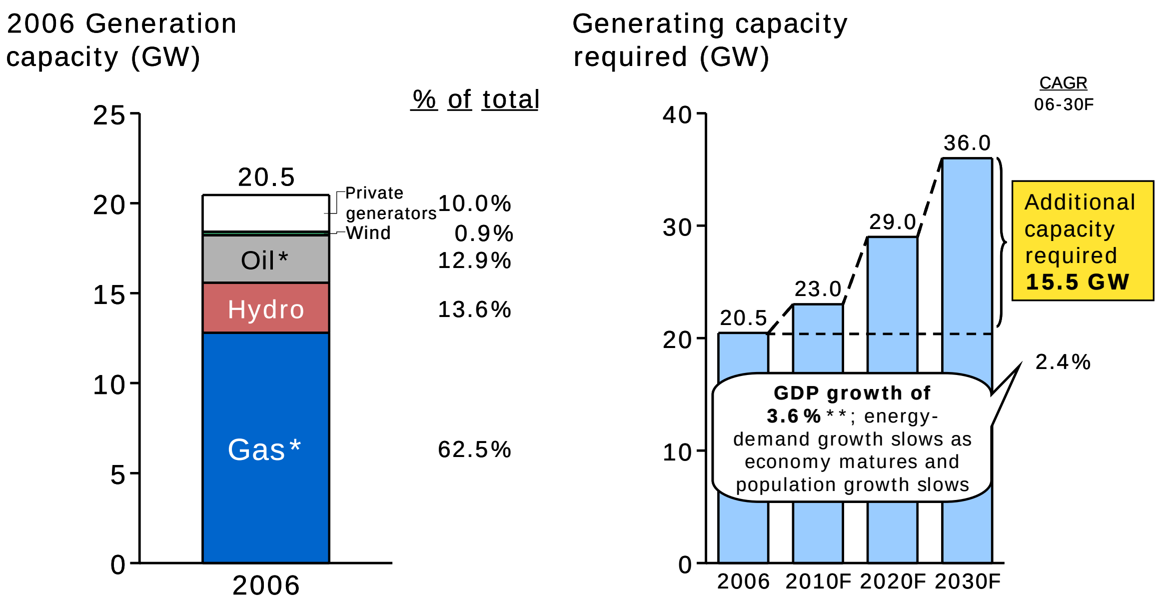
In 2006, Egypt had 20.5 gigawatts of electricity generation capacity.[20] The residential and industrial sector dominate the consumption of electricity at 36.5% and 35.2% respectively, however electricity use from these two sectors have also grown the slowest in the past 5 years at 7.1% and 6.5% per annum, respectively[21]. The government and public sector makes up 12.4% of electricity consumption, and have grown at 8.5% per annum between 2001/02 and 2005/06[22]. The remaining 16.9% of electricity consumption is split almost evenly between commercial, agriculture and other sectors, with the commercial sector growing the fastest at 12.9% per annum for the same time period[23].

The International Energy Agency projects that required electricity generation capacity in Egypt will grow more slowly in the next two and a half decades than it has in the past three decades, at an annual rate of 2.4% between 2006 and 2030[24]. The drivers behind this slowing growth of electricity demand includes a slowing

[20] Egyptian Electric Holding Company Annual report 2005/06
[21] Ibid
[22] Ibid
[23] Ibid
[24] International Energy Agency, "World Energy Outlook 2005 – the Middle East and North Africa Insights"

economy which is projected at 3.6% GDP growth over the same time period due to an aging population, as well as a maturing economy that tends to be less energy intensive[25]. With this projection, Egypt would need 15.5 gigawatts of additional generation capacity by 2030.

Figure 11. Egypt's current and projected generating capacity



*Sources and notes: *Gas and Oil generation capacity estimated based on total "thermal" generation capacity in 2006 and average ratio of gas to oil generation capacity in 2003 and 2010F **GDP growth rate from 2003-2030; Egyptian Electric Holding Company Annual Report 2005-2006; Demand projection from World Energy Outlook 2005 – the Middle East and North Africa Insights, International Energy Agency*

The importance of natural gas in Egyptian electricity generation has grown dramatically during the late 1990s following heavy foreign investment in the Egyptian gas sector and dwindling oil production[26]. In 2006, 62.5% of the electricity generation comes from gas-fired turbines owned by the Egyptian Electricity Holding company, 13.6% from hydropower plants, and 12.9% from oil[27]. Renewable sources other than hydropower make up an insignificant amount of generation. In addition, approximately 10% of the electricity generated comes from private operators licensed by the government, a vast majority of whom use gas-fired turbines[28].

In the next two and half decades, natural gas powered plants will likely continue to play an increasing role in Egyptian electricity generation, with the share of oil powered plants declining slightly, and other power sources such as hydro, wind, and

[25] Ibid
[26] Ibid
[27] Egyptian Electric Holding Company Annual report 2005/06
[28] Ibid

other renewable energy contributing only very slightly to the 15.5GW additional generation capacity required by 2030[29].

Natural Gas. Natural gas will most likely be the greatest contributor to new electricity generation until 2030, making up more than 90% of the additional capacity required. Egypt has made a few recent major discoveries and has seen its gas reserves increase dramatically[30], currently at 68.5 trillion cubic feet[31]. Significant investment has increased Egypt's production capacity to roughly 5 billion cubic feet per day in 2007. Even though Egypt is at the same time building up its capacity to export its natural gas, the government is deeply concerned about maintaining adequate supply for domestic use. To this end, it has limited gas reserves available for export to 25%, down from a third from previously[32]. Most of the planned buildup in electricity generation has focused on gas. Already, there are enough confirmed projects to add 5.4 gigawatts of gas capacity to Egypt[33]. An additional 9.2 gigawatts of gas-fired capacity is expected to meet 2030 demand[34].

Oil. As Egypt's oil reserves dwindle and production drops, the use of oil for electricity generation will continue to decrease. Over the next two decades, there are no plans to construct anymore power plants fueled by oil. In fact, one or two oil powered plants are likely to be retired, leading to the shrinking of absolute capacity from oil powered generation[35].

Hydro. Development of new hydro resources will most likely be limited. Egypt's largest hydro resources have already been exploited in the large Aswan Dam projects, leaving comparatively smaller opportunities. A few smaller projects, however, are already in the plans. Four hydro power units in Naga Hammadi are due to complete May 2008 with combined 640 megawatts of capacity, a project in Kanater Delta in Damietta to complete 2010 with 130 megawatts of capacity, and another at New Asiut Barrage scheduled for 2014 with 320 megawatts of capacity[36].

Renewables. The Egyptian government has not made any serious efforts to invest in renewable energy development. There are a few isolated projects in the plans, including a wind power projects in the Suez, financed by Netherland, with ~60 megawatts generating capacity, and a combined solar/gas power project at Kureimat which is subsidized by the Global Environment Facility that will have ~31 megawatts of solar capacity[37]. Taken together, and without further government policies supporting aggressive development, renewable sources will only contribute marginally to the additional generating capacity required by 2030.

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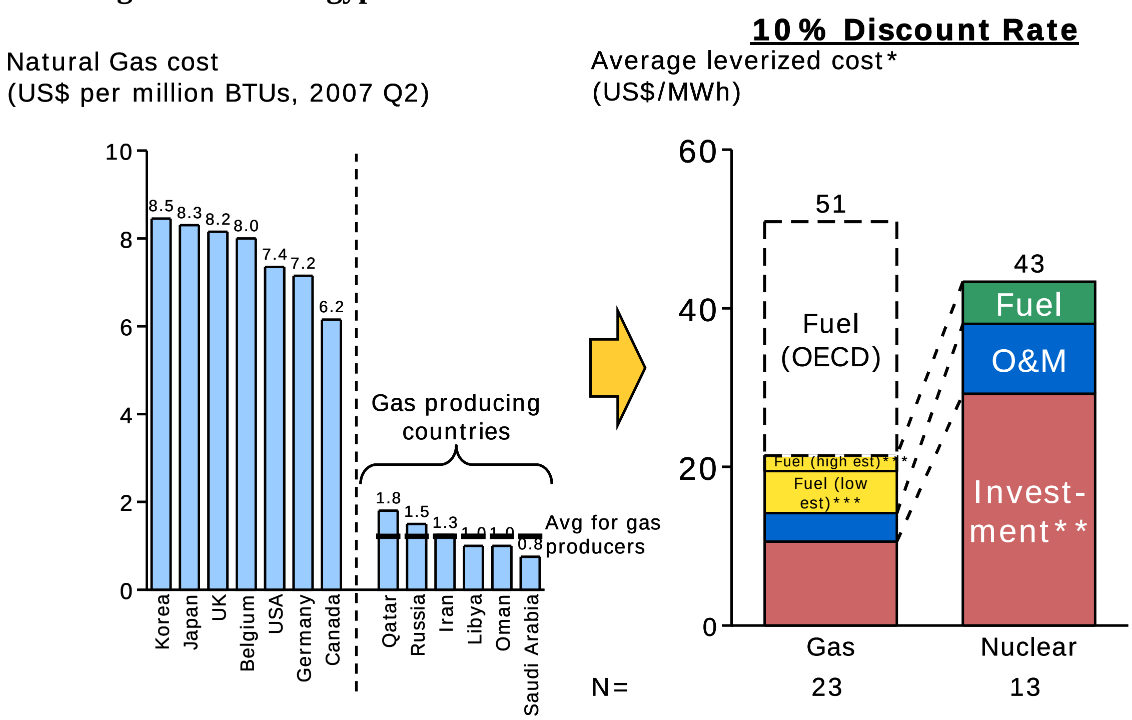
[29] International Energy Agency, "World Energy Outlook 2005 – the Middle East and North Africa Insights"
[30] Energy Information Administration, "Country Analysis Brief – Egypt", 2006
[31] CIA World Factbook, "Egypt", 2007
[32] Ibid
[33] Egyptian Electric Holding Company Annual report 2005/06
[34] International Energy Agency, "World Energy Outlook 2005 – the Middle East and North Africa Insights"
[35] International Energy Agency, "World Energy Outlook 2005 – the Middle East and North Africa Insights"
[36] Egyptian Electric Holding Company Annual report 2005/06
[37] Economic Intelligence Unit "Egypt Country Profile 2007"

Nuclear. At the encouragement of President Mubarak to prioritize nuclear energy development for Egypt, the Egyptian Ministry of Electricity and Energy has officially authorized the construction of three nuclear power plants in al Dab'ah region in Egypt's northwest with a total generating capacity of 1.8 gigawatts[38]. According to the plan, the first plant will enter into force in 2015-16, with the other two scheduled for completion by 2017-18 and 2019-20 respectively[39]. If successful, these three nuclear plants will contribute to ~5% of Egypt's electricity generating capacity by 2030.

Relative Cost

As with the case for Saudi Arabia, the cost of gas generation is significantly lower than world average given much lower cost for fuel in a gas producing country. The average cost for gas producing countries is approximately \$1.2 per million BTUs, compared to the range of \$6 to \$8 faced by import markets (see Figure 12). As a result, the relative costs between natural gas and nuclear generation are vastly different in Egypt, with nuclear costing \$43 per megawatt hour and natural gas generation costing less than \$22 per megawatt hour.

Figure 12. Natural gas costs and resulting cost comparison of natural gas and nuclear generation in Egypt



*Sources and notes: *Average of data from survey of new facilities in 21 countries, mostly OECD but also include 4 developing countries. Leverized generation cost include initial investment cost, Operation and Maintenance cost, Fuel cost, and in the case of*

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[38] BBC, "Egypt approves plans to build three new nuclear power stations", September 26, 2006
[39] Ibid

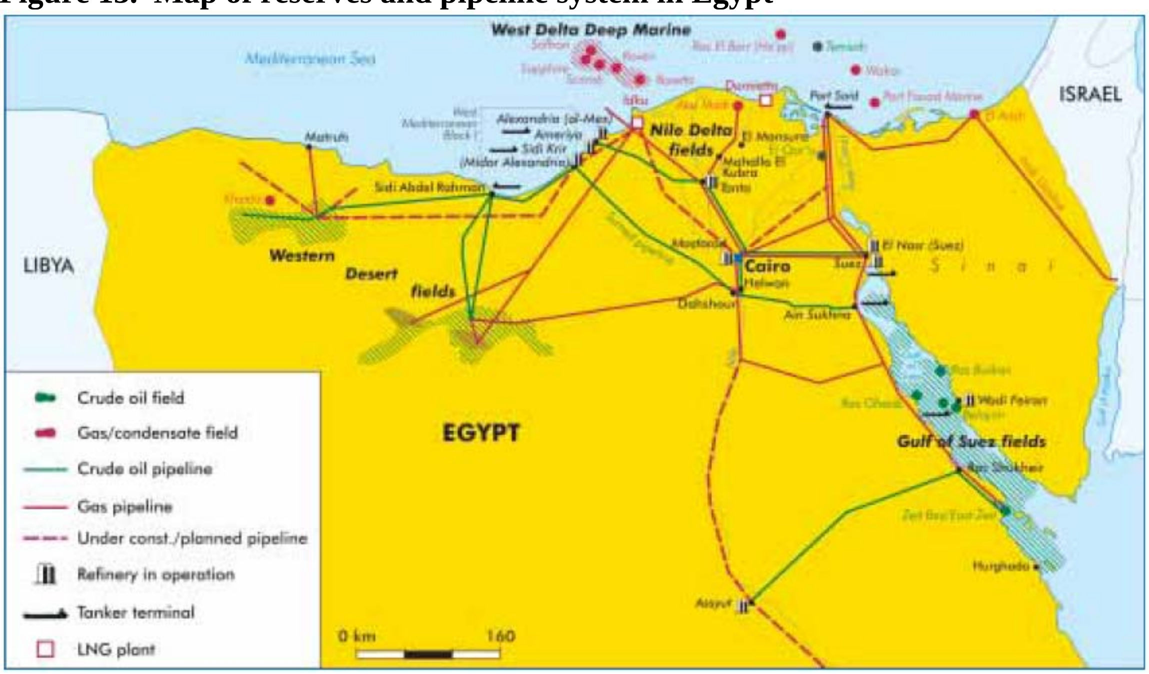
*nuclear; main assumptions – 85% capacity factor for plants, 40 year lifetime for coal and nuclear plants, for other plants lifetime come from country level responses, fuel price projection based on each country's models **Investment cost for nuclear power includes decommission cost ***calculated as average gas producing country's gas price as % of the lowest and highest price in the OECD gas price data available; "Projected Cost of Generating Electricity 2005 Update" – Nuclear Energy Agency / International Energy Agency*

Egypt also faces the potential opportunity cost of exporting LNG versus burning the gas for domestic consumption. Currently, Egypt produces enough gas to both export as LNG and satisfy domestic consumption. There may be a time in the future where supply of gas is not enough to satisfy both, and a choice has to be made between export and domestic use. However, the analysis of opportunity cost for Saudi Arabia shows that current conditions would still favor the use of gas for domestic energy generation until gas prices rise by a significant amount.

Energy security and location of energy source

Egypt has significant natural gas reserves, and has also redoubled its efforts in exploration, with the goal of adding 30 trillion cubic feet of additional reserves by 2010[40]. Given its large indigenous supply, energy security is relatively high. Most of Egypt's gas fields are in near the Nile River delta and the Sinai Peninsula, near its densest population centers[41]. There are also several gas fields, in addition to significant potential, in the Western Deserts which is connected to Cairo via an existing pipeline[42].

Figure 13. Map of reserves and pipeline system in Egypt



Source: World Energy Outlook 2005 – International Energy Agency

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[40] Energy Information Administration, "Country Analysis Brief – Egypt", 2006
[41] Ibid
[42] International Energy Agency, "World Energy Outlook 2005 – the Middle East and North Africa Insights"

Conclusion

In the foreseeable future, Egypt is likely able to rely on its abundant and growing natural gas resources to power its economy. Natural gas supply disruptions are extremely unlikely in the medium term due to its indigenous supply. The cost of natural gas in Egypt is significantly lower than in other nations, so that gas-fired generation is extremely cost competitive versus other power sources, including nuclear. Thus, there is no rush for Egypt to develop nuclear energy from a resource and economic perspective.

TURKEY

Total Potential Capacity

In 2004, Turkey had 36.8 gigawatts of electricity generation capacity[43]. The largest user of electricity is the industrial sector, which in 2004 accounts for 56.9% of electricity consumption[44]. Residential and commercial usage contributed to 22.8% and 12.9% of demand respectively, with the remaining 7.4% of electricity consumption in government and public illumination.[45] Growth projections vary widely, with a low estimate showing total electricity generating capacity required by 2020 growing at 6.4% per annum and the high estimate showing growth to be 8.5% per annum[46]. This would imply that that 63 gigawatts to 99 gigawatts of generating capacity needs to be added between 2004 and 2020. This variation in electricity demand projections made by the Turkish Planning Commission is driven by the demand growth scenarios, with lower estimates assuming a higher mix of low energy intensive industries as part of Turkey's future GDP.

A variety of energy sources can be drawn on to meet the electricity generation demand. In 2004, the balance of sources used to generate electricity was pretty evenly spread between natural gas (41.3%), hydro (30.6%), and coal / lignite (22.9%), with the remaining 5.2% generated by oil and other resources[47]. Within these sources, natural gas has seen the most rapid growth in the past decade. In the coming decades, Turkey will likely diversify its energy supply so as not to rely on any one resource to meet its future electricity demand.

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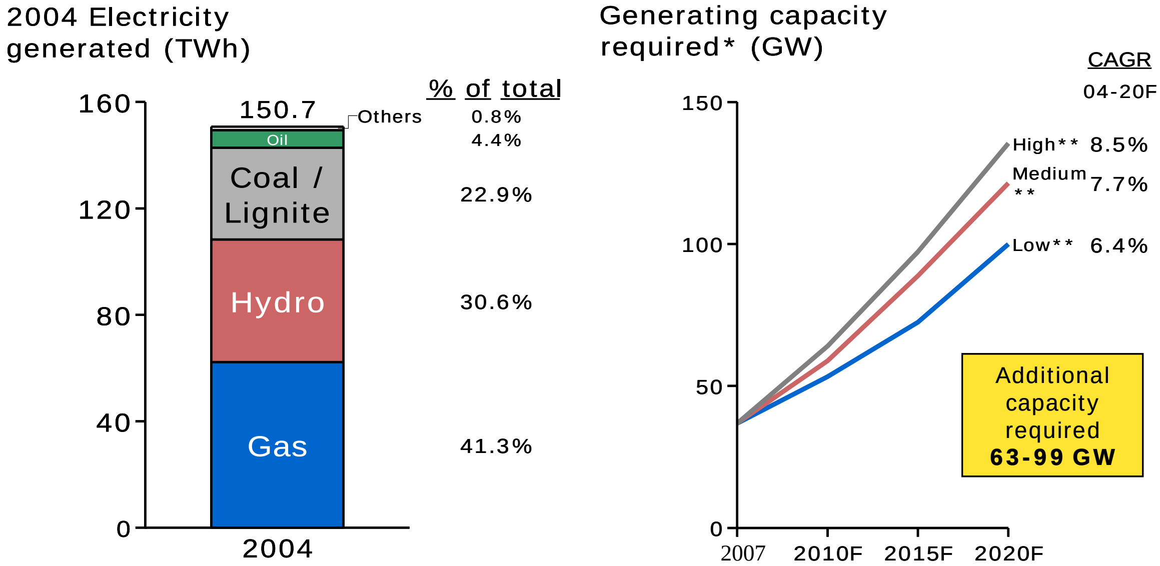
[43] Turkey Statistical Yearbook 2006
[44] Ibid.
[45] Ibid.
[46] Report of Turkey Long Term Electric Energy Demand, 2004. Ministry of Energy and Natural Resources, via "The role of Hydropower in meeting Turkey's electric energy demand" Yuksek, Komurcu, Yuksel, and Kaygusuz. Energy Policy 34 (2006) 3093-3103
[47] Turkey Statistical Yearbook 2006

Figure 14. Turkey's current and projected generating capacity



*Sources and notes: *Generating capacity required projection based on growth rate in electricity generated projection. **MAED-Model for Analysis of Energy Demand by the International Atomic Energy Agency – Scenario 1 is based on GNP growth by the Turkish Planning Organization (DPT) in May 2002, Scenario 2 based on GNP growth planned in Apr 2004, Scenario 3 assumes different production industry prediction than Scenario 2 (TBD), from Report of Turkey Long Term Electric Energy Demand), 2004. Ministry of Energy and Natural Resources. Source: Turkey Statistical Yearbook 2006;*

Natural Gas. Natural gas will most likely be the largest contributor to new electricity generation in the medium term. Turkey faced a financial crisis in 2001 which led to a contraction of the economy and subsequently a downward revision of its natural gas demand. This meant, however, that Turkey now has a significant over-supply of natural gas, stemming from a large number of natural gas import contracts signed previous to the economic contraction[48]. Thus, until the 2015-2020 time-period, tightness in supply of natural gas should not be a problem for Turkey. Given the numerous advantages of natural gas, from low emissions to ease of use as peak-load resource, the Turkish government is supportive of continuing to build more gas-fired power plants.

Hydro. Hydropower will also likely to be a main contributor to new generation capacity. Turkey is extremely well-endowed with hydro power resources, which currently already contributes almost a third of its electricity generation. The government has ambitious plans to continue to develop the sector. It is currently undertaking a number of large projects, particularly the $32 billion Southeastern Anatolia Project (GAP) in the Tigris and Euphrates basin. The project would add a total of 22 dams and 19 hydro stations, representing 7.5 gigawatts of generation power, as well as tremendous irrigation capacity[49]. Phase I was completed in 2005 and the entire project should be completed by 2010. Some experts forecast even greater potential for hydro power, claiming that total

[48] Energy Information Administration, "Turkey – Country Analysis Brief", October 2006
[49] International Energy Agency, "Energy Policy in IEA Countries – Turkey" 2005

generating capacity from hydro can reach 45 gigawatts by 2020, which would represent between 33%-46% of the generation capacity required by 2020, depending on growth scenario[50].

Coal. Coal and lignite will continue to be a part of the electricity generation scenario but more likely to be used as backup resources, perhaps to hedge against higher future gas prices. Two main reasons underlie why the government and the Turkish power sector has started to de-emphasize coal. First, the indigenous coal in Turkey is of a very poor quality. Less than 7% of its total reserve of coal is "hard coal"[51], whereas most come in the form of lignite. Burning lignite and low quality coal is an extremely inefficient method of extracting energy. Second, Turkey's accession to the EU has significantly influenced how it thinks about its carbon emissions. Understanding that as a full fledged member of the EU it will have to participate in a regime of capping emissions, the government has chosen to divert investment away from developing carbon-intensive coal power plants.

Renewables. Renewable resources in Turkey have tremendous potential, but the pace of developing these resources is uncertain. Turkey's long coastline provides some of the best geographic conditions for exploiting wind energy. It is estimated that there are ~90 gigawatts worth of wind power in Turkey, with at least ~10 gigawatts being commercially and economically viable by 2020[52]. Turkey also enjoys one-eighth of the entire world's geothermal energy potential, estimated at 4.5 gigawatts of electricity and 31.1 gigawatts of thermal capacity[53]. While Turkey only has one geothermal power plant, exploratory projects are planned as are plans on how to use the thermal power of these sites to lower electricity demand. Turkey also enjoys high solarization levels and thus quite substantial potential for solar power development[54]. This potential has largely gone untapped, with only one PV based – grid connected solar electricity project. These renewable resources will likely be more fully developed in the future, however, since Turkey recently passed a Renewable Energy Law.

Nuclear. Nuclear power has been proposed as one development path to decrease Turkey's reliance on imported hydrocarbon power. The government has a goal of building three nuclear power plants by 2012 with a total generating capacity of 4.5-5 gigawatts[55]. The first of these planned plants, to be built in the city of Mersin, went to bid by private contractors March of 2008[56]. It remains to be seen whether these plants can be completed in time given the high likelihood of delays in nuclear power plant projects. If successful, nuclear power could provide a small portion of Turkey's generating capacity by 2020.

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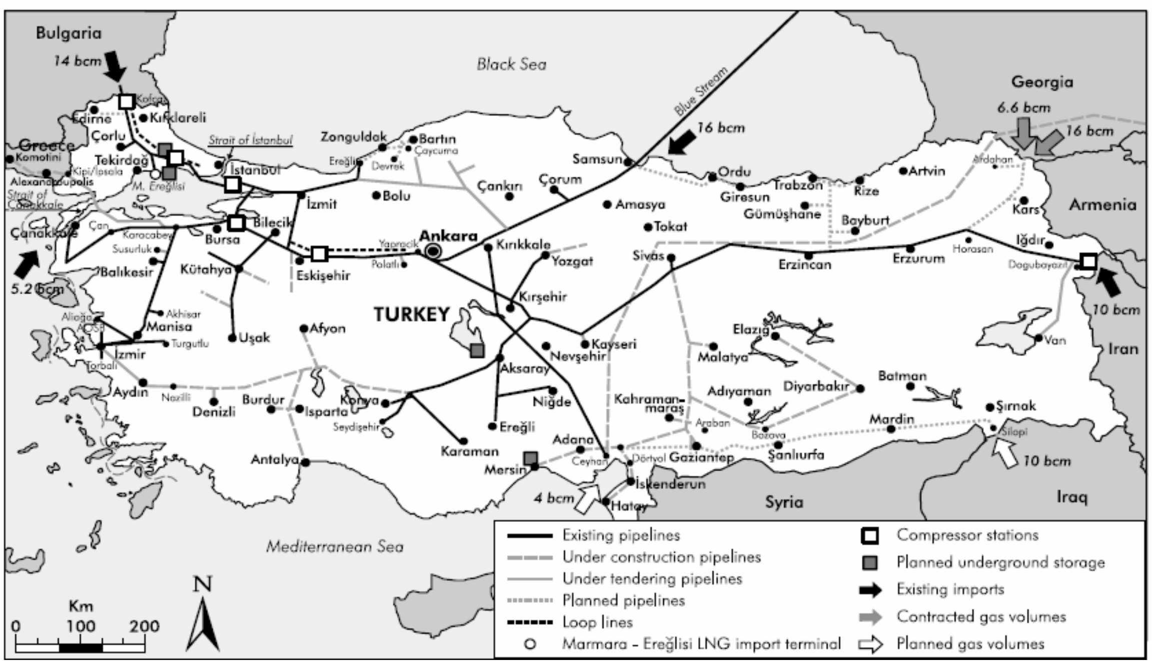
[50] Yuksek, Komurcu, Yuksel and Kaygusuz "The role of hydropower in meeting Turkey's Electric energy demand" Energy Policy 34 (2006): 3093-3103
[51] Energy Information Administration, "Turkey – Country Analysis Brief", October 2006
[52] International Energy Agency, "Energy Policy in IEA Countries – Turkey" 2005, 123
[53] International Energy Agency, "Energy Policy in IEA Countries – Turkey" 2005, 121
[54] Ibid
[55] Energy Information Administration, "Turkey – Country Analysis Brief", October 2006
[56] Associated Press, March 24, 2008

Energy efficiency. Energy efficiency efforts also hold considerable promise in Turkey. Tanay Sýdký Uyar, Vice President of the World Wind Energy Association and Associate Professor of Renewable Energy at Marmara University, estimates that "Turkey can cut its electricity needs by 50% if it uses more up-to-date energy efficient technology"[57]. If Turkey can galvanize around policies that promote the use of more efficient technology in its industrial and building sector, it can be a large source of "Negawatts".

Relative cost

Not being a significant producer of natural gas, Turkey does not enjoy the significantly lower price of gas generation as Saudi Arabia and Egypt but renewable energy resources are likely more cost competitive. According to the IEA, the estimated cost of nuclear power in Turkey could be on par with that of gas generation[58]. However, given Turkey's geographic advantages in wind and geothermal, its renewable energy sources can be potentially more cost effective than in other countries. Country specific estimates place hydro and geothermal power lower than both gas and nuclear, with wind energy on par with gas and nuclear[59]. As such, nuclear power does not have any particular cost advantage in Turkey.

Figure 15. Map of pipeline system in Turkey



Source: International Energy Agency – Energy Policy in IEA Countries – Turkey, 2004

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[57] Yuksek, Komurcu, Yuksel and Kaygusuz "The role of hydropower in meeting Turkey's Electric energy demand" Energy Policy 34 (2006): 3093-3103
[58] IEA 2005 via Erdogdu, Erkan. "Nuclear power in open energy markets: A Case Study of Turkey" Energy Policy 35 (2007):3061-3073
[59] Ibid

Energy security and location of energy source

Other than low quality coal and lignite, Turkey does not have significant deposits of other fossil fuel resources, requiring it to import all of its natural gas and oil. Turkey's largest suppliers of natural gas are Russia and Iran, but it has actively looked to diversify its sources and began importing gas from Azerbaijan and Egypt, as well as LNG from Algeria and Nigeria in the late 1990s[60]. This move to diversify should give Turkey relatively more energy security regarding to importation of natural gas. The second factor that bolsters Turkey's energy security is that it is conveniently located so as to serve as the hub of energy transportation – both for shipping between the Black Sea and Mediterranean Sea and for natural gas pipelines from Russia, Central Asia, and the Middle East which supply continental Europe. Its position should provide Turkey relatively more bargaining power in securing oil and gas supplies. Domestically, the extensive system of pipelines will also ensure that energy supply can be easily transported to where they are needed.

Further reinforcing Turkey's energy security will be Turkey's extensive renewable energy sources. Hydro power, predominantly found in Southeast Anatolia, is well located to serve the Eastern part of the country[61]. Wind power can best serve the large population centers along Turkey's long coastline[62] and geothermal power is found mostly in the Southwest region[63]. Finally, solar power is available throughout the country with relatively high solarization rates. These renewable sources have high potential to be used both for population centers and to provide decentralized generation for dispersed population.

Environmental Impacts

Turkey has moved increasingly toward minimizing its environmental impacts, largely driven by the EU accession process. As the EU accession process draws nearer to close, Turkey anticipates that it will be required to reduce carbon emissions under the next EU Emission Trading System (EU ETS). This has motivated the government to pass the newest Renewable Energy Law to spur development of alternative non-carbon-emitting resources and make the most out of its abundant and multiple sources of renewable energy. It has the opportunity now to push renewable development much faster than it has previously so it can both meet EU emission standards and use emission reductions as a new source of income under the ETS.

[60] International Energy Agency, "Energy Policy in IEA Countries – Turkey" 2005
[61] Energy Information Administration, "Turkey – Country Analysis Brief", October 2006
[62] International Energy Agency, "Energy Policy in IEA Countries – Turkey" 2005
[63] Ibid

Conclusions

Turkey has a wealth of energy resources it can draw upon to meet its electricity demand for 2020, not requiring considerable nuclear development. From a supply perspective, Turkey has relatively secure natural gas import security in the medium term, and can leverage its unique status as energy transport hub to ensure security of supply in the long term. Turkey also has much more abundant renewable energy resources that can be explored to meet demand. From a cost perspective, most of the generating sources in Turkey are on par with price, with certain renewable sources actually on the lower end of the cost comparison. Nuclear power is neither necessary to meet Turkey's future energy demand nor has an overwhelming cost advantage.

CONCLUDING REMARKS

The analysis of the economic and resource arguments for nuclear power energy in Saudi Arabia, Egypt, and Turkey shows that they are not as strong as politicians have articulated. In all three countries, there are alternative resources, either indigenous or comparatively secure, that, fully developed, can meet growing energy demands without additional investment in nuclear power. There is little confidence in the supposed cost advantage of nuclear power generation, given that cost calculation of nuclear plants, even in the United States and France, is obscured by a tradition of heavy government subsidization and existence of long lists of ancillary costs. This cost advantage becomes negative when evaluated against gas generation in many of the Middle Eastern nations that have significant gas production. Furthermore, nuclear development requires a considerable degree of public and private sector cooperation which is best served by a high degree of government effectiveness, considerable regulatory strength, and a tight control on corruption. When even countries with such advantages struggle with nuclear development, it suggests that countries with fewer such advantages may find it more challenging to develop nuclear power safely and effectively.

One key consideration in the potential development of nuclear power is when countries need to make a decision. Given that the countries under evaluation have secure and cost effective options in the medium term, a decision to develop nuclear power is not required at this time. The nuclear industry is seeking to initiate a revival in the West, with potentially safer and cost effective designs which would make nuclear power more attractive on both a cost and environmental basis. Developments are also underway on a variety of renewable energy sources as alternatives which could significantly lower their price and make them more feasible. With other resources to exploit, Saudi Arabia, Egypt, and Turkey can postpone decisions on nuclear power development and focus instead on developing the regulatory quality and governance needed to successfully execute such development. Furthermore, given the current economic and financial challenges facing the world, however, projects that require less upfront capital and allow building capacity incrementally may be favored by investors and governments.

ABOUT THE AUTHORS

Peter Tynan is a Partner in Dalberg's Washington DC office. Peter's focus has been advising international development institutions, corporations and investors on emerging markets issues and investments. At Dalberg, Peter leads the Access to Finance Practice and co-leads the Energy Practice. Peter most recently advised the U.S. Overseas Private Investment Corporation on their investment of $500 million in global energy funds, which catalyzed over $1.5 billion in total investments. Peter also advised the Asian Development Bank on their $100 million investment in energy funds in Asia, performing due diligence on some of Asia's leading energy fund managers. He has worked with US private equity firms to devise emerging market entry strategies to enter India and Africa, and led the development of the fund raising plan for a medical tourism investment project in the Bahamas. He co-led the World Bank/Gates Foundation initiative to create a global subsidy for anti-malarial drugs, by using innovative global financing mechanisms to reduce the price of anti-malarial drugs for patients.

Prior to joining Dalberg, Peter worked for J.P. Morgan in Hong Kong, and as an Investment Executive in a boutique private equity firm in Australia, where he sourced and evaluated middle-market private equity investments.

Peter holds an MBA from Harvard Business School, a Masters in Public Policy from the Kennedy School of Government at Harvard University. He is the co-author of 'Will the US-India Civil Nuclear Cooperation Light India?' in Gauging US-Indian Strategic Cooperation (Strategic Studies Institute, 2006) and Imagining Australia: Ideas For Our Future (Allen & Unwin, 2004), and regularly speaks on renewable energy issues.

John Stephenson is a Project Manager in Dalberg's Washington DC office and has expertise in energy issues related to South Asia, East Asia, and Africa. John jointly managed Dalberg's support to the U.S. Overseas Private Investment Corporation for their investment of $500 million in global energy funds. John also provided analytical support to Dalberg's effort with the Asian Development Bank to select fund proposals for $100 million in energy investments in Central Asia and East Asia. John coauthored with Peter Tynan 'Will the US-India Civil Nuclear Cooperation Light India?" in Gauging US-Indian Strategic Cooperation (Strategic Studies Institute, 2006), which looked specifically at renewable energy opportunities within the context of India's energy needs and other supply options through 2032. On this topic, John has presented at the Carnegie Endowment for International Peace and the report was cited in the Economist. Previously, John evaluated sustainable business models for energy technologies as part of the energy access scale up strategy for the East African Community. This entailed working closely with the UNDP, UNEP, and East African Community officials to identify sustainable, largely renewable energy based business models in Uganda, Tanzania, and Kenya. The strategy included detailed investment programs, action plans, policy harmonization, capacity building, program management, and financing strategies which were subsequently endorsed by energy ministers and launched in 2006. John has also worked extensively with the World Bank on governance issues in the extractive industries as well as with private equity fund managers on their investment strategies in emerging markets.

John holds a Master's degree in International Security from Georgetown University's School of Foreign Service and a Bachelor's degree *magna cum laude* in Government and East Asian Studies from Harvard University.

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