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Clean Energy Investment in Developing Countries:

Wind power in Egypt

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IISD's Bali to Copenhagen project carries out research, analysis and networking on trade and climate change in six thematic areas: border carbon adjustment; liberalization of trade in low-carbon goods and services; investment; intellectual property rights and technology transfer; subsidies for greenhouse gas reductions; and fossil fuel subsidies. For more on IISD's work on trade and climate change see www.iisd.org/trade/crosscutting, or contact Aaron Cosbey at acosbey@iisd.ca.

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1.0 Introduction

1.1 Background

IISD has a major Trade & Climate Change Programme running in 2008–09. One of the focus areas is *investment*, which includes a case study on the historic and possible future development of wind power in Egypt. The case study is designed to demonstrate the issues around encouraging significant clean energy investment within developing countries that are net exporters of fossil fuels.

Wind power development in Egypt has many points in its favour:

- Egypt's wind resource is one of the best in the world;
- There is ample land available with low alternative economic value;
- Demand for electricity and other sources of energy is increasing significantly;
- Air quality considerations in the major cities are one of the key environmental concerns;
- Donor support has been extremely strong, including studies, capacity building and grants.

Yet wind generates just 0.7 per cent of Egypt's electricity supply.[1] This case study:

1. describes the development of wind generation to date, within the context of the development of the energy and electricity sectors;
2. analyzes the factors supporting and constraining investment—what these have been to date and how they might develop in the future;
3. discusses the conditions that would be necessary for a large-scale implementation of wind power in the future.

1.2 Keeping track of changes in the Egyptian energy sector

This case study examines the situation in March 2009 and analyzes important changes known to be either in the system or being considered at this time. Many aspects of the Egyptian energy sector are currently in the process of changing or change has been proposed. This includes, *inter alia*, elements relating to the costs of electricity transmission and distribution; new laws relating to the incorporation of wind power; pricing of gas, electricity and other energy carriers; whether wind components will be constructed in Egypt and how new wind plants will be tendered. Progress in a number of areas is expected in the second half of 2009, though the precise dates and impacts of these changes exhibit significant uncertainty.

[1] 831 GWh out of 125,129 GWh in 2007/08 (Egyptian Electricity Holding Company Annual Report 2007/08)

2.0 Energy in Egypt

2.1 Overview

Egypt has traditionally been a net exporter of energy. Until the late 1990s, these exports were of oil; oil production has declined from its peak in the early 1990s and is now roughly matched to Egyptian consumption. The discovery and exploitation of large reserves of natural gas mean Egypt is now a significant exporter of gas, both by pipeline and as liquefied natural gas (LNG).[2]

Egyptian energy policy has been driven by considerations of how oil and gas should be exploited and how they should be used domestically and for export. Electricity generation has been a major source of demand for fossil fuels. Previously, Egyptian power generation was dominated by oil but now natural gas dominates, representing three-quarters of the power generated. The remainder comes from the Aswan Dam hydro-electricity complex and from heavy fuel oil ("mazut").

The development of wind power must be seen within the context of the development of fossil fuels in Egypt. This section discusses oil, gas and electricity generation, describing their historical development and future prospects.

2.2 Oil

Egypt has traditionally been a net exporter of oil. Figure 2.1[3] shows that production declined at an average of 3 per cent/year over the period 1995–2005, while domestic demand has continued to grow. Net exports in 2007 were 60 thousand barrels per day, down from a peak of 500 in 1993.

Whilst Egypt continues to be a small net exporter in physical terms, its balance of trade in oil has been negative since 1999 (ERM and Environics, 2003). Eight of Egypt's nine refineries are relatively old and simple. They produce large quantities of low-value products (particularly heavy fuel oil and naphtha) and insufficient quantities of high-value products (notably diesel and LPG).[4] Furthermore, many of the products do not meet international standards—gasoline tends to be of relatively low octane number and high sulphur content.[5]

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[2] Liquefied natural gas is the form used for the transport of gas by ship

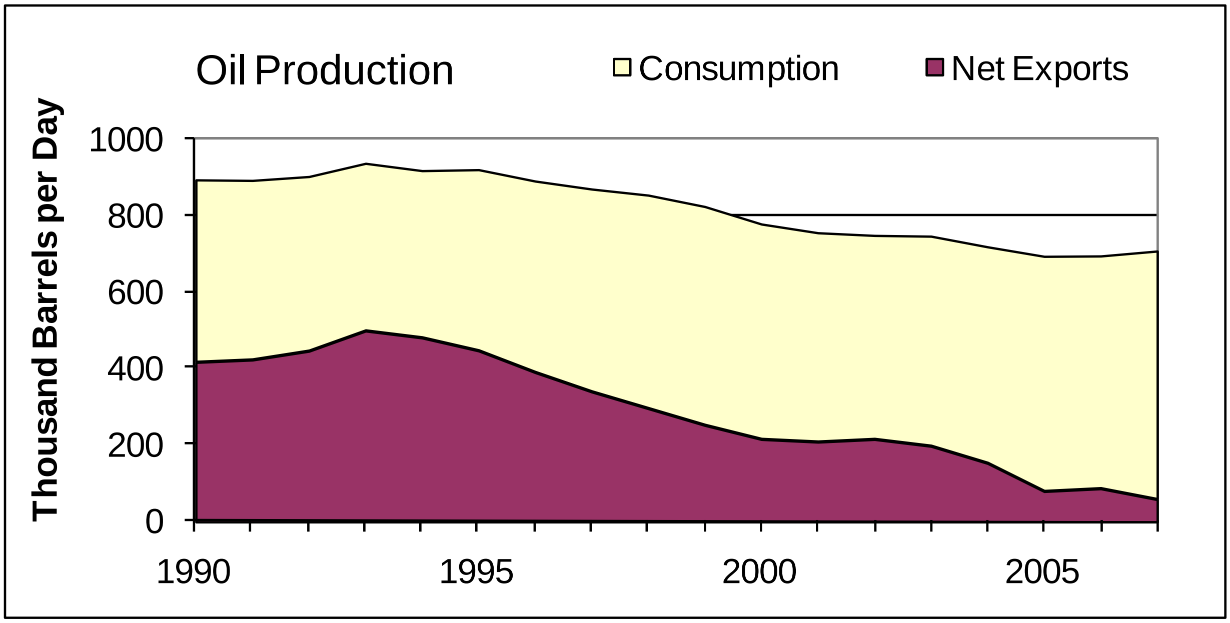
[3] Source: BP, 2008.

[4] A number of hydrocracking/desulphurization facilities are currently being established in Egypt, including one in Northern Cairo, producing lighter products from heavy fuel oil (HFO) produced by the Cairo Oil Refining Company, and another as an independent refinery in the Suez Area using crude oil inputs and HFO from National Petroleum Company of Suez.

[5] Diesel sulphur content averages around 0.4 per cent from the eight older refineries. (ERM and Environics, 2003)

The move from positive to negative balance of trade is often associated with a change in energy policy, notably in tariffs charged. When the balance of trade becomes negative, countries are more incentivized to charge prices that reflect their full costs.

Figure 2.1: Oil production in Egypt, 1990–2007



2.3 Natural gas

Natural gas has been produced offshore in Egypt since 1970 (from Abu Qir, east of Alexandria; and Abu Madi in the Nile Delta). Production levels became significant when associated gas from the Suez Gulf came online in 1983.

Figure 2.2 shows that production more than quadrupled over the period 1995–2007. Exports require the development of infrastructure: they started with the completion of a pipeline to Aqaba, Jordan in 2003 but became significant only in 2005, when the LNG plants at Damietta ("SEGAS") and Idku ("Egyptian LNG") came online. Exports are now 15 bcm (billion cubic metres), one third of Egypt's production. Egypt's proved gas reserves continue to grow; the IEA projects that both production and exports of natural gas will double between 2005 and 2030 (IEA, 2005).[6]

Gas was first used as an alternative fuel in Egypt for power generation, via the conversion of oil-fired thermal cycle plants. A relatively small quantity of open cycle gas turbine plants were added in

[6] Production is projected to increase to 82 bcm in 2030 and exports to 36 bcm. The study notes Egyptian government estimates of probable or possible reserves to be as high as 2800–3400 bcm

the early 1980s, and a number of larger plants (including Combined Cycle Gas Turbine [CCGT]) have been constructed more recently. These plants were specifically built to burn gas. Around 90 per cent of thermal Egyptian generation currently uses natural gas.[7]

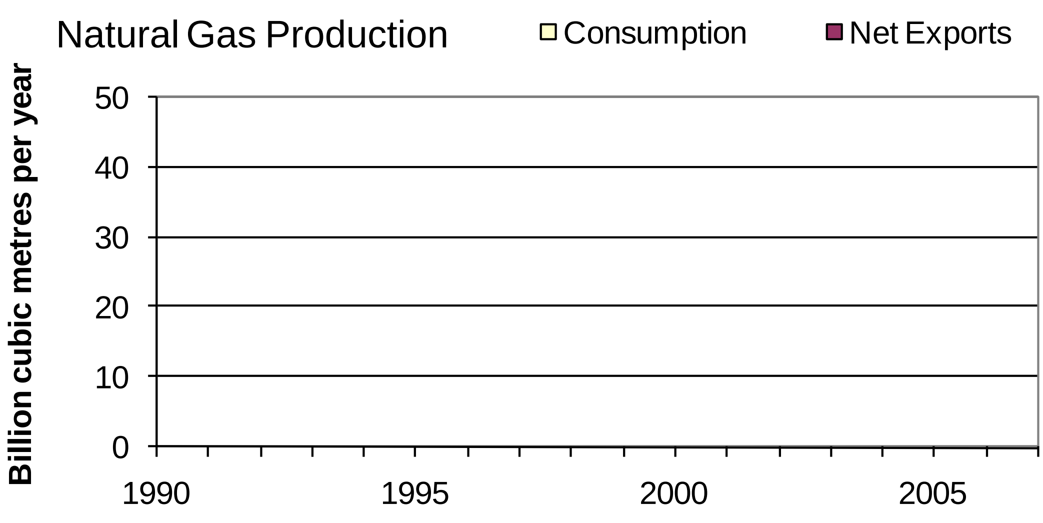
Power plants are major consumers of gas and can use new supplies of gas quickly (in that they need only single lines to be constructed). The wider gas network is being progressively built up. Large customers were the first connected: in many cases, energy-intensive plants such as fertilizer and cement plants were located in Egypt to take advantage of the availability of gas. Concessions to construct the network were granted and the number of customers with smaller demands continues to increase.

Power plants continue to dominate Egypt's domestic gas demand. They were responsible for 63 per cent of demand in 2006, with industry (14 per cent) and the energy sector's own consumption (11 per cent) making up the majority of the remainder (IEA, 2006b).

Egypt has dealt with its expanding gas resources by adopting, since 2000, a gas strategy comprising:

- One-third for local needs;
- One-third for medium-term export commitments;
- One-third for long-term strategic requirements. (Fahmy, 2000)

Figure 2.2: Natural gas production in Egypt, 1990–2007



[7] All figures taken from Egyptian Electricity Holding Company (EEHC) Annual Reports (http://www.egelec.com).

2.4 Electricity generation

2.4.1 Development of capacity and generation to date

When the Aswan Dam complex was developed in the 1960s, it was able to meet the vast majority of Egypt's electricity demand. Hydro-electricity still represented 50 per cent of Egypt's capacity in 1980 (see Figure 2.3) but, due to major increases in electricity demand, had fallen to less than 15 per cent in 2006. Hydro capacity has been essentially constant at 2842 MW (2007/08) and will not alter significantly in the future; Egypt has dammed its only major river and has only limited remaining opportunities to add to its hydro capacity.

Egypt's electrification program has been successful and electricity is supplied to 99 per cent of the population. Capacity has quadrupled over the past 25 years, with average capacity additions of 600 MW per year (i.e. one large power plant every two years). New thermal capacity was first based on steam turbines, burning mazut.[8] In the early 1980s, approximately 700 MW of "open cycle"[9] Gas turbine capacity was added, with a further 1200 MW added over the past three years. The first 860 MW of combined cycle gas turbine capacity was added in 1989 and it has been gradually built up to today's capacity of 4000 MW.

Other than hydro, renewable capacities are limited. The installed wind capacity at the end of financial year 2006/07 was 310 MW (see Section 4 for a full discussion of the development of wind). There are a number of small solar installations of a trial nature, including the 140 MW hybrid thermal/solar generation power plant (120 MW thermal and 20 MW solar), which is currently under construction and planned to start operation in mid 2010 (NREA, 2007).

Institutional structure and ownership

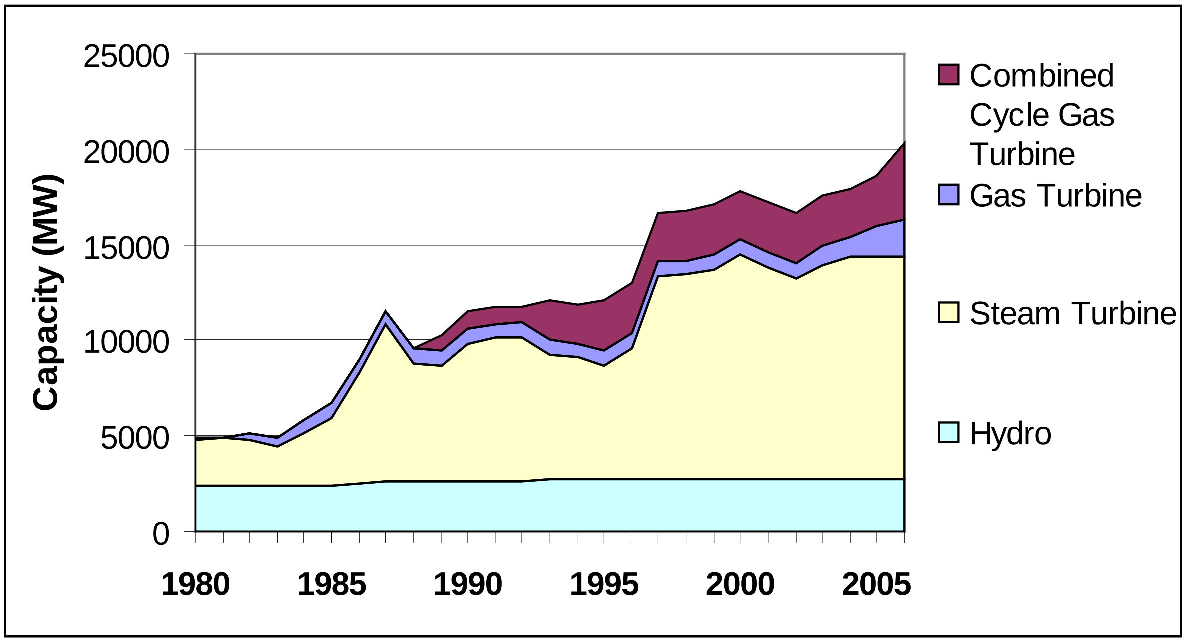
The institutional structure of the electricity industry is an important determinant of how different technologies and fuels are favoured over others. Egypt's power sector is dominated by the Egyptian Electricity Holding Company (EEHC),[10] a state-owned organization that was set up in 2000 as part of plans to liberalize the electricity sector (IEA, 2005).

A number of independently-owned new gas generation plants were built under "BOOT" arrangements, whereby their ownership will be transferred to the state after 20 years. The most important of these are three natural gas-fired CCGT plants, which have a total capacity of just over 2000 MW. These are now owned by PowerTech of Malaysia and operate under the proviso that they can only sell their electricity to the government-owned transmission network. A limited number of small-size generating utilities were licensed to operate since the establishment of the electric

[8] Heavy fuel oil (HFO), essentially the residue from the refining process, known locally as Fuel #6.
[9] Open cycle gas turbine plants include turbines using gas. Combined cycle gas turbines add steam turbines to recover energy from the exhaust gas of the gas turbine. This increases both electricity generating efficiency and capital cost.
[10] Law number 12 for the establishment of the Egyptian Electricity Holding Company.

regulatory agency in 2001; their overall capacity and number of customers is growing gradually (they currently account for around 100 MW of capacity [Egyptian Electric Regulatory Agency, n.d.).

Figure 2.3: Generating capacity, 1980-2006[11]



2.4.2 *Future electricity needs and plans*

Egyptian electricity demand is projected to continue to grow strongly. The latest National Development Plan issued in 2007 (MOEE, 2007) calls for the addition of 8000 MW of new capacity between 2007–12; EEHC is planning to add a further 33,900 MW of thermal capacity over the period 2012–2027.[12] Taken together, these plans envisage the net addition of approximately 40,000 MW of new capacity over the next 20 years—an average of 2000 MW per year. This is equivalent to 10 per cent of total current generation.

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[11] Capacity figures for Hydro, Gas Turbines and Combined Cycle Gas Turbines are taken from EEHC Annual Reports, with total thermal capacity figures from the U.S. Energy Information Administration used to calculate figures for steam turbines (see http://www.eia.doe.gov/emeu/international/contents.html).

[12] Formal presentations during 2008 and 2009 on the electricity sector's expansion plans by MOEE and EEHC, such as: a) North Africa High level roundtable on sustainable regional development at the World Bank Washington DC-22 February 2008; b) Presentation entitled *Egyptian Power Projects Briefing* presented by EEHC August 27, 2008 to potential bidders to Elsokhna power plant; c) presentation by the MOEE first under secretary to the National Party Committee on Energy, February 22, 2009.

The National Development Plan and EEHC plans give an indication of what share of the thermal plant would be steam turbine and what would be combined cycle gas turbine.[13] The plans envisage a continuation of the current role of fossil fuels, with gas being the fuel of preference and dominating generation, while oil will continue to be used in its current role as a balancing fuel to ensure that export commitments for natural gas can be met.[14] Developments in fuel markets could possibly alter this consideration, but gas and oil prices tend to be strongly linked and the continuation of gas's dominant role appears a good assumption.

As discussed above, the possibility of new hydro going forward is severely limited. Large-scale solar development within the next 20 years is also not considered a significant possibility: there is no national target or road map and the Mediterranean Solar Plan envisages less than 1 GW of capacity within the period (Ministère, 2008). The potential role for wind is a much more open question. Section 4 discusses the plans that the Government of Egypt has for wind. These envisage a potentially very large expansion from the current 310 MW to somewhere between 5,000 and 10,000 MW in the next 20 years. Whether such plans will be implemented will depend on co-ordinated planning with how natural gas is used.

One development that could have a major impact in the future is the idea that Egypt, and other countries in North Africa, could utilize their excellent wind and solar resources to generate electricity for export to the European Union via a Mediterranean ring or an undersea cable (Ministère, 2008). The attraction of the idea for Egypt is that such electricity generated may qualify for European renewable incentives, which are currently far more valuable than carbon credits under the Clean Development Mechanism (CDM) of the Kyoto Protocol. In order to develop such opportunities, major new electricity transmission infrastructure would be required, along with agreements governing the eligibility of electricity generated. Both of these would represent major challenges and there is little precedent: in common with most countries, Egypt's trade of electricity is low (2006 saw net exports of 0.3 per cent of Egypt's generation (IEA, 2006a) with a slight increase to 0.45 per cent in 2007/08.[15]) The option is not discussed further in this paper.

[13] Of 7375 MW of total thermal capacity for 2007–12, 3375 MW (45 per cent) is projected to be combined cycle; of 33900 MW for the period 2012–27, 10500 MW (30 per cent) is projected to be combined cycle.
[14] The gas available for power generation is that produced minus exports and the demand of non-power sectors within Egypt. Any shortfall in this amount would be met by using oil for power generation in existing steam turbine plants. Over the past decade, gas has been used for over 90 per cent of total thermal generation. The IEA (2005) projects gas taking up all new electricity generation in Egypt to 2030 other than a minor role for renewable other than hydro (in turn dominated by wind).
[15] According to EEHC Annual Reports

3.0 The Potential of Wind Power

The potential for wind depends on there being a good wind resource, on wind generation being sufficiently close to the transmission grid to allow economic connections to be made and on the fact that there are no other issues that preclude wind development (for example, radar communications close to military installations). Whether this wind potential can be developed economically depends on the costs of wind in comparison to alternatives: these considerations are discussed in Sections 6 and 7 of this paper.

3.1 The wind resource

A precondition for developing wind power is that the wind resource is understood.[16] This means understanding wind speeds across the year: a good wind resource is one where wind blows through a large proportion of the year and where the speed is sufficiently high to drive a wind turbine at a high power rating, without being so high that turbines would be stopped for fear of damage.

The wind resource in Egypt is well understood. The New and Renewable Energy Authority (NREA) has done extensive work over the past 13 years, building a very comprehensive state-of-the-art wind atlas for Egypt in cooperation with Risoe National Laboratory. Wind resource estimates for the El-Zayt Gulf area have, according to Risoe National Laboratory, been conducted at a level that would be suitable for developing bankable projects using WAsP calculations on the basis of local anemometer measurements. Meso-scale mapping (lower resolution and lower precision estimates) has been made for all other areas of Egypt.

Figure 3.1 shows an extract from the atlas, at a typical turbine hub height of 50m above the surface. Areas in red, pink and purple are those where the power density is above 400, 500 and 600 W/m^2 respectively, that is to say, where the wind resource is sufficient to allow the possibility of economic development. The economics of areas in yellow (where the wind power density is 300–400 W/m^2) are marginal economically.

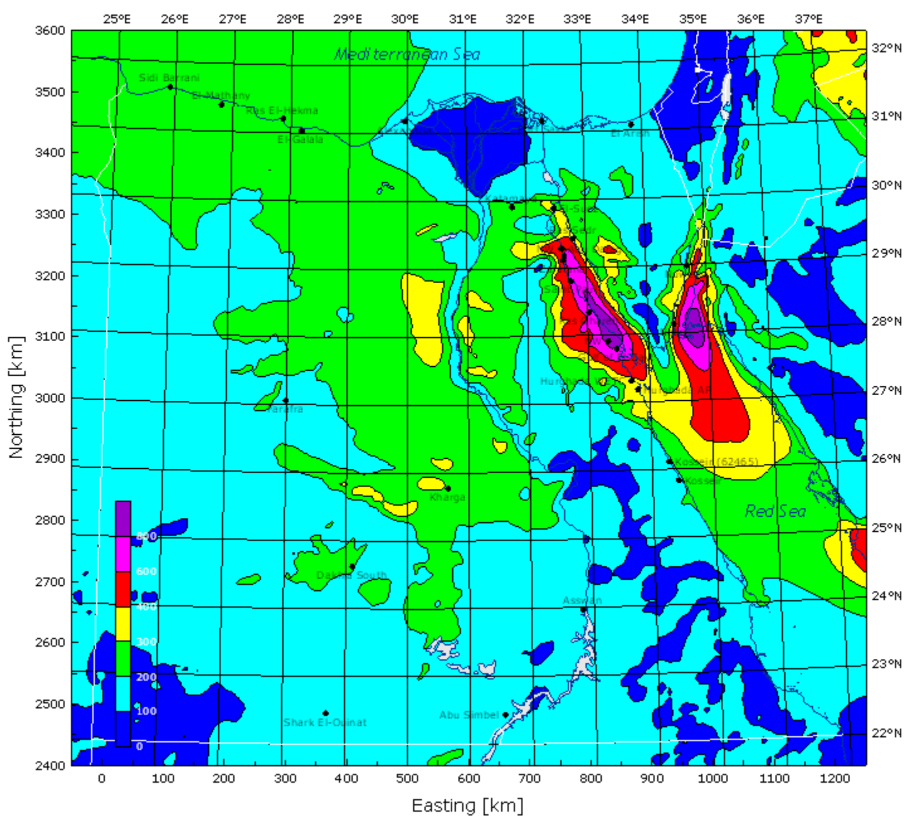
There are very significant wind resources in Egypt, particularly on the Red Sea coast, where mean wind speeds are in the range of 8–10.5 m/s at 25m (NREA, 2007). According to the wind atlas, the following major areas with sufficient wind energy resources have been identified:

1. **Gulf of Suez** area (wind power density 400–600 W/m^2; 400–500 W/m^2 nearer to the city of Suez);

[16] See for example 3 Tier (n.d.), *REmapping the World,* which states that, "there are three major obstacles to the adoption of renewable energy: the availability, the accessibility and the usability of renewable energy resource information"

2. **Gulf of Aqaba** area (400–600 W/m^2);
3. **Western Egypt domain at the west bank of the Nile** (300–400W/m^2);
4. **Eastern Egypt domain at the east bank of the Nile** (300 W/m^2);
5. **Western desert – areas close to Kharga** (300–400W/m^2).

Figure 3.1 - Wind atlas for Egypt (Power density at 50m, in W/m^2)



3.2 Geographic issues that impede wind development

The five areas of Egypt with significant wind potential demonstrate a number of issues that impede their full-scale exploitation:

1. The **Gulf of Suez** covers 2000 km^2 onshore. The area is partially used for oil and gas exploration and production; pollution from flares reduces the area available for wind power. The southerly Gulf El-Zayt region includes a main transit route of migratory birds, which has reduced the estimate of potential capacity (Decon/Fitchner, 2008). The existing Zafarana developments are at the northern boundary of the area. Further developments in the area require further studies—the perceived constraints due to pollution and bird migration may be found to have been overstated;

2. The **Gulf of Aqaba** coastal area is largely a nature reserve. Offshore, the water depth is quickly over the 200m limit considered uneconomic for offshore wind development. The development of floating wind turbine solutions may offer some possibility in the future, providing that environmental issues can be dealt with;
3. The **Western Egypt domain at the west bank of the Nile** has no issues other than its relatively low wind power density, which has yet to be confirmed by detailed measurements;
4. The **Eastern Egypt domain at the east bank of the Nile** has lower power density than the western area and is further from the transmission grid. Its development should therefore follow that of the western area;
5. The **Western desert—areas close to Kharga** are far from densely-populated areas. The costs of connecting to the power grid are likely to be prohibitive.

It is the Gulf of Suez area that is thus most suitable to wind power development. The Zafarana site, where wind speeds average 8.5 m/s, housed 305 MW of Egypt's 310 MW of wind power in 2008; more capacity is planned for the site. A feasibility study for a 3,000 MW development has been proposed for the Gulf El-Zayt, where average wind speeds of 10.5 m/s are amongst the highest in the Middle East and North Africa region.

Egypt's Wind Atlas contains some guidance as to the potential scale of wind power. By 2022, at least 7,200 MW could be implemented within the Gulf of Suez and a further 1,000 MW on the west and east banks of the Nile. These estimates are bound by issues including both time and finance, and are thus relatively conservative: the potential resource could be many times higher, but would require higher payments per unit of electricity generation and development over a longer time period.

3.3 Incorporating wind power into the grid

There is no technical limit to the amount of wind power that can be incorporated into the electricity grid. The issue is one of cost: long transmission lines are clearly more expensive than shorter ones; as the proportion of wind in the grid increases, more provision has to be made for controlling the quality[17] of the power in the grid and higher levels of back-up power or storage are required.

Many studies provide detailed descriptions of the issues involved with incorporating wind power.[18] A figure of 20 per cent of total system capacity is often used as a rule-of-thumb as a limit within which established control methods and system reserves would remain adequate (Greenpeace, *et al.,* 2008). This figure is indicative and the actual figure is system-dependent. What we can conclude with both transmission capacity and with the ability of the system to incorporate wind, is that there are a number of steps that will require major additional costs to be overcome. For Egypt, an

[17] Phase, voltage, frequency, etc.
[18] For a good, simply-presented introduction to the issues see Greenpeace, *et al.,* 2008.

international consultant is currently working with the Transmission Company to plan how a major expansion in wind capacity (up to almost 20 per cent of the current generation capacity by year 2022) could be incorporated.[19]

The **Gulf of Suez** area is around 250 km from Cairo, considered an acceptable distance for the transmission of large quantities of power. The current grid contains a high voltage (220kV) line to Zafarana. It is estimated that the current grid could take 1500 MW of wind[20] (according to the capacities of transformer substations in that area), which is about 7.5 per cent of the current Egyptian electricity generation capacity. The future grid connection of the wind farm area of Gulf El-Zayt would be through an interconnection of the present 220 kV lines that end in Zafarana and Hurghada respectively. This power line has not been built, but is in the planning stage at present. With 420 MW already in feasibility planning for El-Zayt Gulf (in cooperation with Germany and Japan), it is planned that the transmission be both upgraded and expanded into a ring form. These changes, scheduled slightly ahead of the completion of the wind farms, would avoid transmission congestion and hence avoid the need to limit which wind farms could despatch energy.

The plans for very substantial additional wind development in the Gulf El-Zayt area will certainly require a very substantial upgrade of transmission capacity to the area. The following map (see Figure 3.2) shows the planned extra- and high-voltage networks by year 2017; this network will accommodate the additional targeted wind farms' capacity. Currently, the associated Terms of Reference for these expansions are under preparation. According to the Decon-Fichtner study, the cost for a two-circuit 500 kV overhead line sufficient for 3,000 MW is approximately $500,000 per km (note that U.S. dollars, at current values, are used throughout this report unless otherwise indicated).

There is already a very good infrastructure around the city of Suez, and grid reinforcement[21] would not be required.

The **Western Egypt domain at the west bank of the Nile** is close to the existing 500 kV transmission line between Aswan and Cairo, so little grid reinforcement would be expected.

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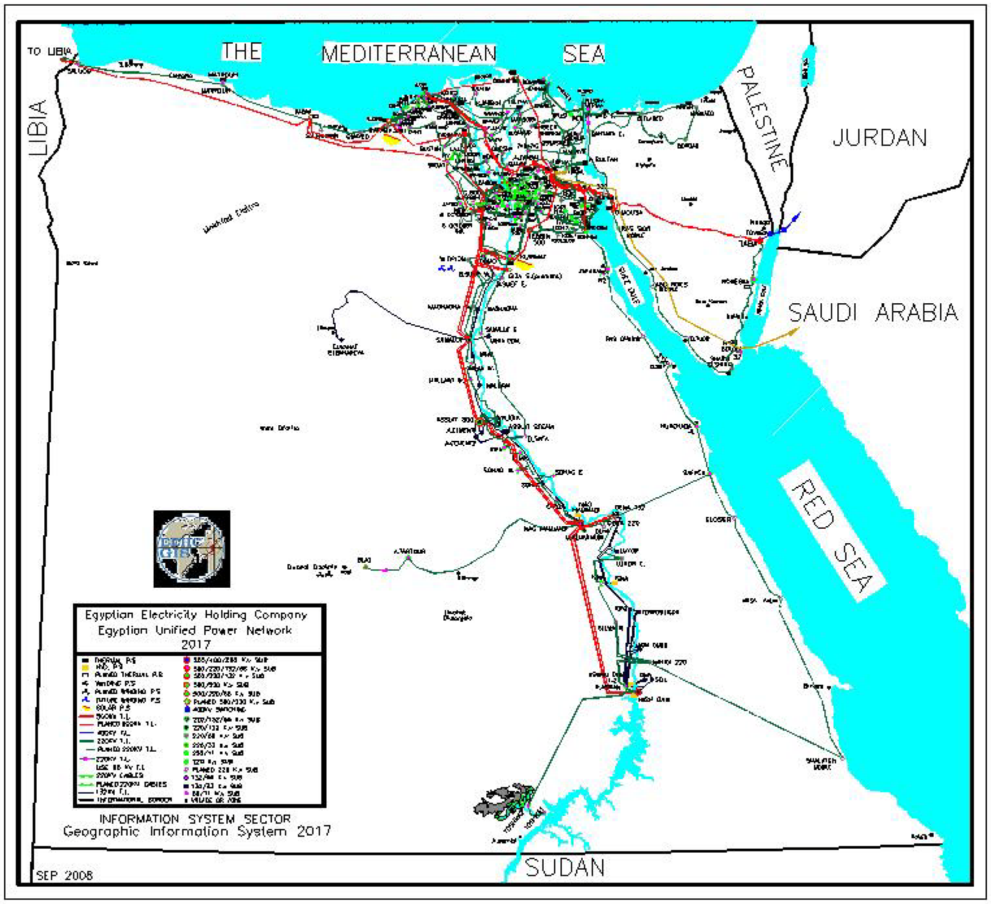
[19] The results of the study are not in their final stage. In this paper authors' view, additional extra and high voltage transmission and associated substation capacities in 2022 would need to be about 70 per cent of the targeted wind capacity in order to transmit the anticipated wind energy generated without congestion. This estimate has been conducted based on the current characteristics of the Egyptian electricity system and its diversity factor at the extra and high voltage levels.

[20] Author's (ElSobki) estimate, based on the current available transmission network capacities and system diversity and load factor

[21] Increasing the capacity of some or all of the grid, be this lines, transformers, etc.

Figure 3.2: Planned extra and high-voltage networks by 2017



3.4 A further possibility

A feasibility study for a wind power development for an Italian-owned cement plant's own energy needs is believed to be underway, with a capacity of 120–400 MW. A memorandum of understanding has been signed by NREA and the developer to address issues including siting. Whether electricity would be exported from the site to the grid is unclear: if there is export, then wheeling charges would be applied (these are currently approximately around 1 Euro cent/kWh [approximately UScents 1.3/kWh] for the high voltage and above networks[22]).

[22] In accordance with announcements on the regulatory site, http://www.egyptera.org.

4.0 Development of Wind Potential to Date

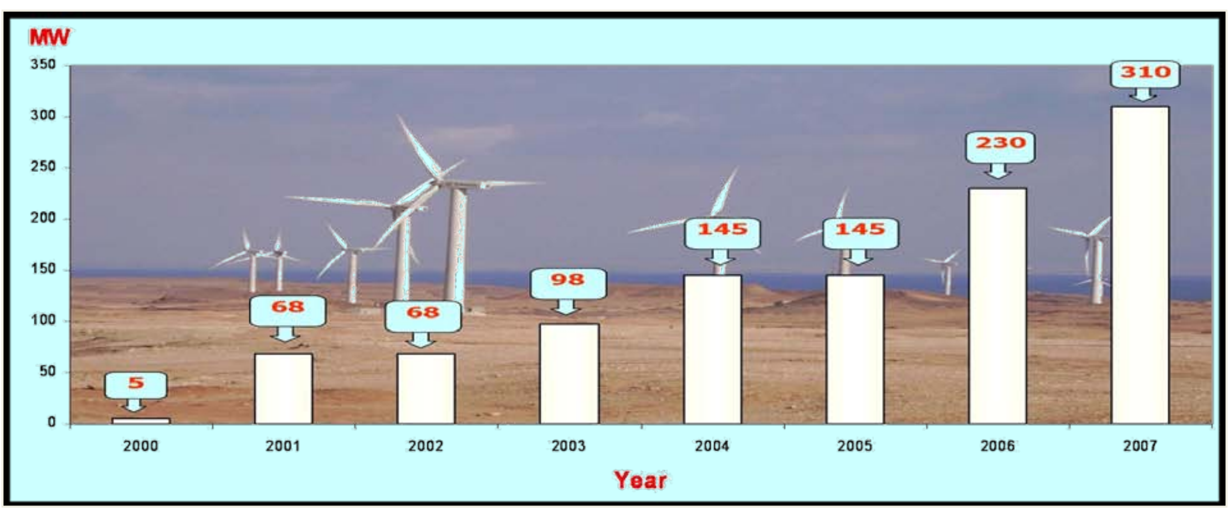
4.1 Capacity

Egypt started its wind energy program in 1993 with a 5.2 MW pilot plant and demonstration wind farm in Hurghada. This wind farm consists of 42 wind turbines ranging between 100 and 300 kW; the towers and blades were manufactured locally.

All following projects have been in the Zafarana area on the coast of the Red Sea; the current total operating capacity is 305 MW, giving a 2007 total for all of Egypt of 310 MW when the turbines at Hurghada are added in. All existing wind farms in Egypt are owned and operated by NREA. The availability rate for the wind farms at Zafarana exceeds 98.5 per cent, in line with international experience.[23]

Figure 4.1 shows an annotated timeline of capacity development. These projects were executed though funds and technical assistance from Denmark (60 MW, 2001–03); Germany (80 MW, 2001–4); Spain (85 MW, 2006) and Japan (80 MW, 2007). The German, Spanish and Japanese developments have all applied for accreditation under the CDM, using methodology ACM2 (grid-connected electricity generation).

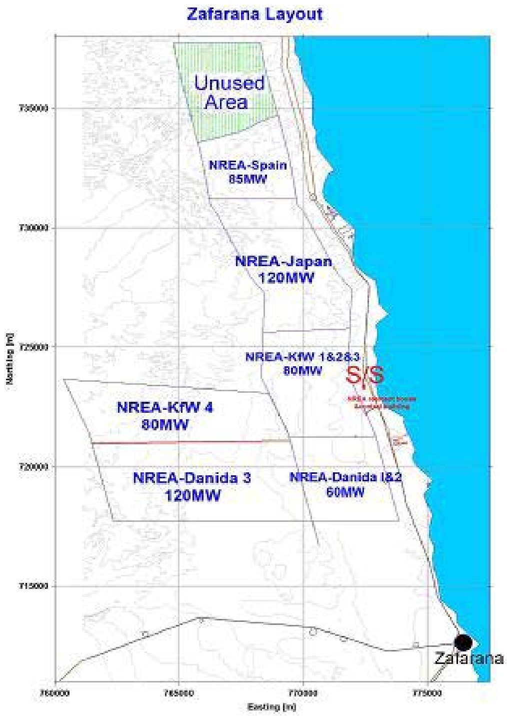
Figure 4.1 Development of wind farm capacity



[23] The IEA's *Renewable Energy Essentials: Wind* (2008b) states a technical availability figure of 99 per cent. This figure does not take any account of the proportion of time the wind blows or its speed.

There are firm plans for a further 280 MW at Zafarana in the near future. This would bring total capacity at the site to 585 MW, located as shown in Figure 4.2.

Figure 4.2: Current and planned wind farms at Zafarana



4.2 Institutional structure

NREA was established in 1986 to undertake research and to develop renewable sources in Egypt on a commercial scale, as well as to implement energy conservation and efficiency programs. Under the direction and leadership of NREA, there has been considerable research into the feasibility of renewable energy systems in Egypt, most notably related to solar power and wind power systems. In 1996, NREA produced the first wind atlas for the Gulf of Suez and in 2003 published an updated Wind Atlas for Gulf of Suez , and then a Wind Atlas for Egypt as a whole in December 2005.

NREA's role currently includes both planning and development. This is appropriate during a demonstration phase when gaining experience is a key goal. Large-scale wind implementation, particularly within an electricity market that is being liberalized, ideally requires a separation of functions. Conflicts of interest can arise because of reasons that include:

- NREA currently develops the rules governing the assigning of land for wind farms for its own wind farms as well as for those of potential competitors;

- NREA’s role as national planner for renewable energy as well as project developer.

Legal unbundling of the planning and development roles of NREA is needed so that wind energy development in Egypt is not hindered; two separate entities could be set up.

5.0 Plans for Future Development of Wind

5.1 Overview

Egypt's has planned major extensions to its wind capacity for many years. Plans cover two phases:

1. The period to 2012, within which NREA will continue to own schemes developed with finance from overseas donor agencies.[24] Capacity additions are planned to average 200 MW per year.
2. The period after 2012, when private-sector developments are expected to add anywhere between 400–1000 MW of new capacity per year.

Large-scale implementation requires the movement from phase one to phase two, away from donor financing to private-sector financing. For such a move to take place, private-sector investors will need a financial environment that allows them to recover their investment over the long term, and confidence that the environment will not become unfavourable during this period.

5.2 Short-term plans[25]

Egypt has not been able to build up its wind capacity as quickly as it has wished. It was planned that wind would be responsible for five per cent of electricity capacity (requiring approximately 1,000 MW of total installed capacity) by 2010, but the latest target is now three per cent (approximately 600 MW of capacity). These figures correspond to approximately three per cent and two per cent of electricity supply respectively.

The latest plan is shown in Table 5.1 and Figure 5.1. In October 2008, NREA was working on three specific projects in the Gulf of Suez area:

1. 200 MW with KfW (Germany) financing (expected operation in 2012), request for consultancy service is already issued;
2. 120 MW with Spanish financing (expected operation in 2012);
3. 120 MW with JBIC (Japan) financing (expected operation expected operation in 2013).

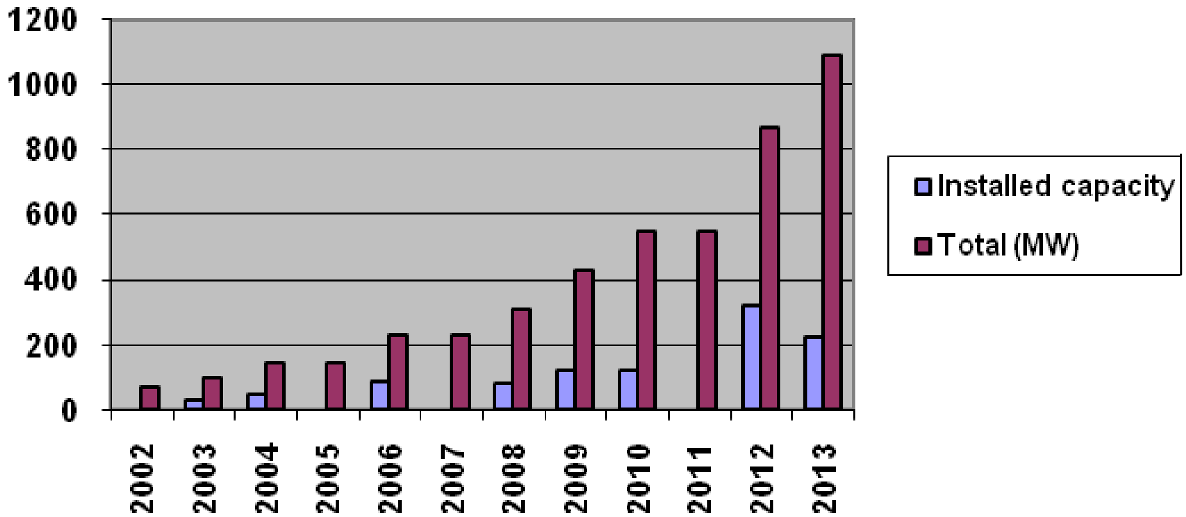
[24] Initial financial support to wind developments in Egypt was in the form of grants. Soft loans were then provided, and donors now typically offer a combination of soft and commercial loans. Donors effectively pay a share of the extra costs of wind generation compared to alternatives, with the Government of Egypt contributing a (typically smaller) share (Source: telephone conversation with Engineer Rafik Georgy, consultant to NREA).
[25] NREA (2008) and formal presentations by the electricity regulator at a number of workshops during 2008 and 2009, such as the one on February 4, 2009 addressing the Regional Center for Renewable Energy and Energy Efficiency (RCREEE) at its round table meeting (http://www.rcreee.org).

Similar projects will be developed to meet the plan of 1,090 MW installed capacity by the end of 2013. All plants will be at the Zafarana or Gulf El-Zayt sites.[26]

Table 5.1: NREA wind farm capacity in Egypt (operating and planned projects as of October 2008)

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Installed capacity (MW)	0	30	47	0	85	0	80	120	120	0	320	220
Total (MW)	68	98	145	145	230	230	310	430	550	550	870	1090

Figure 5.1: NREA wind farms total installed capacity in Egypt (past, current, short-term)



5.3 Longer-term plans

In April 2007, the Supreme Council of Energy (SCE) elaborated on a plan to increase the share of wind energy such that it would represent 12 per cent of total electricity demand in the 2020–2021 fiscal year.[27] This would require wind capacity to reach 7500 MW by 2020, as shown in Table 5.2 and Figure 5.2. Were such a plan to be realized, Egypt would become one of the major wind users in the world.

The shadowed area in Table 5.2 requires the completion of a 220 kV transmission line to Gulf El-Zayt, which is currently under construction. Similarly, the development of the "private" sector

[26] 420 MW of the capacity is planned for the Gulf El-Zayt site, in cooperation with Germany and Japan.
[27] Two papers on *Energy and Development* by the National Democratic Party Energy Committee (2007; 2008), in coordination with SCE (in Arabic), are adapted as an outline for an overall energy strategy for Egypt.

capacities from 2013 are based on the assumption that necessary grid reinforcements would be completed by mid-2013.

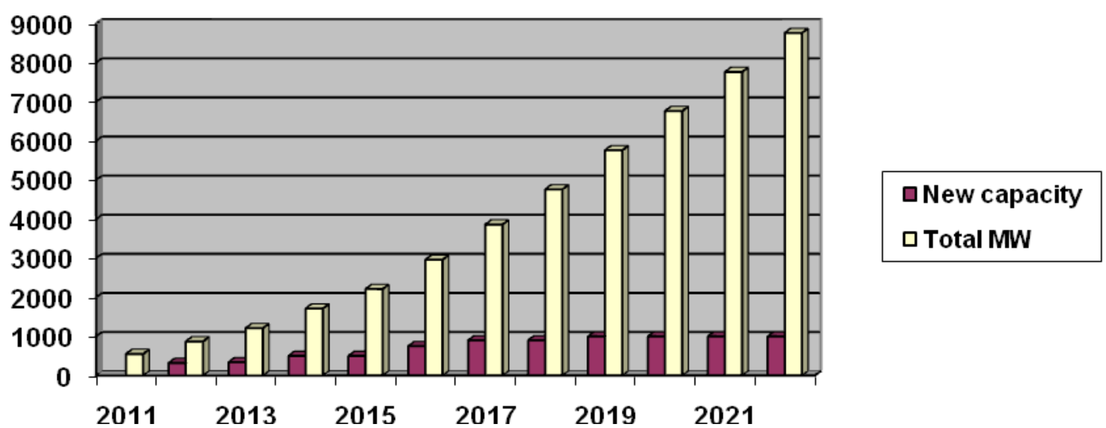
Details of implementing the longer-term plans are still under discussion between the Minister of Electricity, EEHC, NREA and the Regulator. The developments would be Independent Power Producer (IPP) projects with power purchasing agreements (PPAs) with the Egyptian Electricity Transmission Company (EETC). Key issues include:

- financing and completing the necessary grid reinforcements in a timely manner (see above);
- whether plans should be based on relatively small developments (of the order of 250 MW) or much larger developments (of the order of 2,500 MW);
- whether the developers should be offered a fixed tariff or whether they should bid competitively for the price they are willing to supply at;
- how local manufacturing could be encouraged;[28]
- how the legal and regulatory framework could be best refined and strengthened.

Table 5.2 Tentative time schedule for additional wind farm capacities

Year		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
New capacity (MW)	NREA		320	220									
	private			120	500	500	750	900	900	1000	1000	1000	1000
Total MW		550	870	1210	1710	2210	2960	3860	4760	5760	6760	7760	8760

Figure 5.2: Tentative time schedule for additional wind farm capacities



[28] Note that China and India have managed to expand their wind capacities whilst building up local capacity—see Section 7.2.2 for more details.

6.0 The Economics of Wind Power in Egypt

6.1 Introduction

Previous sections have described how gas and oil are used within Egypt and as export fuels, the potential of wind power and the current and planned development of wind power. It has been noted that meeting Egypt's plans for large-scale implementation of wind would require a move away from the current model of financing by foreign donors to private sector investment.

Private sector investors need financial conditions within which they can return profit. Present arrangements see NREA selling electricity to the government-owned transmission company at 14.6 Pt/kWh[29] (UScents 2.5/kWh).[30] This price is significantly below the generation costs of commercial wind farms.

Economic analysis needs to consider what the costs of wind are compared to the alternatives, *from the perspective of Egypt as a whole*. This is an important consideration when, as is the case within Egypt, some tariffs for the purchase and sale of fuels and electricity do not reflect their costs of production and/or their value on the world market. What we are trying to establish is whether wind power represents an economic option for electricity generation in Egypt: if it does, then policies, regulation and incentives should be set to encourage its development. The economic analysis now presented goes through the following steps, using the units presented in Box 6.1:

- *Alternative(s) to wind*: if wind were not developed, what would be?
- *Tariffs for fuel purchases and electricity sales*: how do these compare to their economic costs?
- *Costs to Egypt of wind power and alternative(s);*
- *Comparison of the costs of generation of wind to alternative(s).*

[29] I Egyptian Pound = 100 Piastres, i.e. 1 EGP = 100 Pt. An exchange rate of US$ 1 = EGP 5.5 (average Interbank rate over the period January 1, 2008 to February 26, 2009, www.oanda.com) is used throughout this paper.

[30] This price is composed of 12.6 Pt/kWh (subject to an annual increase of five per cent) plus an additional 2 Pt/kWh from avoided fossil fuel use, which is transferred to a fund to support renewable energies. Source: Annual Technical, Commercial and Financial Report 2007/08 for electricity companies under EEHC (limited circulation); the figures were also mentioned by electricity sector officials when responding to clarifications during workshops organized by donors.

Box 6.1: Units used in this paper

- US dollars ($), at current values, are used for currency values unless otherwise stated.
- The Egyptian Pound (EGP) is made up of 100 Piastres (Pt). The exchange rate used is $1 = EGP5.5.
- The cost of electricity capacity is generally stated in $million/MW (MegaWatt, or million Watts). Multiplying by 1,000 gives the equivalent in $/kW (kilowatt, or thousand Watts).
- Electricity prices are quoted in either $/MWh or UScent/kWh. $10/MWh = UScent 1/kWh.
- Gas prices are given is $/MMBtu, i.e. US dollars per million British Thermal Units.

6.2 Alternative(s) to wind

Section 2 demonstrated that natural gas is currently the fuel of choice for electricity generation in Egypt and is projected to be so for the next two decades. Oil is likely to continue to perform its current role of meeting short-term balancing requirements when gas commitments to exports or non-power uses within Egypt mean there is insufficient gas to fully supply the power sector.

In terms of economic opportunities to develop other bulk generators of electricity, Egypt has no coal; nuclear power brings a whole range of issues with it including high capital costs and a very long lead time in setting up a program and building plant; and the Aswan Dam has already captured the vast majority of potential hydro-electricity generation. Whilst there has been much recent press coverage of a potential "North African Solar Grid,"[31] which would export electricity from concentrated solar plants to Europe via high voltage direct current (HVDC) undersea cables, ideas are at a conceptual stage and implementation would require both political agreements and agreements of tariffs that would be acceptable to European consumers and to project investors. Such tariffs may be considerably higher than current wholesale electricity prices.

Any wind plant built will help Egypt avoid needing to build natural gas plant, at least in the short- and medium-term. However, new natural gas plants generally use generic combined cycle gas turbine (CCGT) technology, which is available from a number of suppliers, on a commercial basis. As a result, natural gas-fired CCGT should be considered the alternative to wind power in Egypt: both at the present time and for the next two decades.

6.3 Tariffs for fuel purchases and electricity sales

6.3.1 Setting the economic price for natural gas

The costs of exploration and production of fuels do not necessarily indicate how fuels should be priced. For example, the cost of producing crude oil varies markedly across the world, but there is a

[31] See for example Pearce, 2008.

single world price.[32] If a low-cost producer sold oil lower than this world price, they would be losing the opportunity to make additional profits resulting from their low cost of production.[33]

The concept of "opportunity cost" also applies to natural gas. The opportunity cost of natural gas is determined by the price paid for gas at locations to which the gas can physically be supplied, that is, on the infrastructure connecting supplies to domestic customers and import/export markets. The "opportunity cost" principle states that the price of a good should be set at the price of the most profitable alternative. By using the good in its current way, we are forgoing the opportunity of using gas in the alternative manner. A loss in opportunity cost may not appear intuitively to be a subsidy but it is widely accepted to be so when the issues are explained.[34]

There is a surplus of natural gas in Egypt. The opportunity cost is thus the net value of export; more specifically, as there is limited gas pipeline capacity for export, it is the net value of export as LNG. If gas were not used for power generation, it could be exported as LNG—by using it for power generation we are thus forgoing the value of this export, which sets the price for gas that should be charged to power generators.

The capital cost of the 3.6 million tonnes/year LNG liquefaction plant built in Egypt in 2003 was $900 million; discounting at 20 per cent over a 15 year economic lifetime, and adding in the value of the approximately 8 per cent of the gas processed liquefaction consumes, gives a typical levelized cost of liquefaction of $1.5/MMBtu.[35] This cost should be subtracted from the world price of gas to give the value of gas to Egypt.[36] Note that US dollars per million British Thermal Units, $/MMBtu, is a standard unit for gas consumption.

Gas export prices are confidential and are only released with the permission of both contracting parties. Verbal interviews have established that current (April 2009) export prices for Egypt's natural gas are of the order of $2.2/MMBtu. Care must be taken as to what the opportunity cost is: LNG exports are generally based on long-term contracts (typically of 15 years), which set a volume and a

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32 Although this world price is really a benchmark with adjustments being made for differences in the constituents of crude oil (e.g. hydrocarbon mix and concentration of pollutants such as sulphur and vanadium). These adjustments tend to be constant; when the world price of benchmark crude oil moves up or down by $1/bbl, so does the price of all crudes.

33 In economic terms, the difference between the price and production costs is known as the "resource rent." In the example given, the low cost producer would be losing part of this resource rent by selling below the world price.

34 "Subsidies usually benefit certain categories of consumers or social classes. However, politicians have to communicate as clearly as they can that there are also costs associated with these subsidies—financial, economic and environmental—borne by everybody. People understand that if energy is provided at below market prices it is more likely to be used wastefully. One of the things we always say is that politicians need to work harder at explaining to the general public just what the costs are involved in subsidizing energy" (Morgan, 2008).

35 Assuming a world gas price of $8/MMBtu and converting GJ to MBtu (multiply by 1.055)

36 It is understood that Egypt's commitments to LNG exporters are often too high to allow domestic demand to be met. In this case, Egypt buys back some of the committed gas. The LNG exporter would charge Egypt the world price of gas minus the 8 per cent that would be required for liquefaction, i.e. a reduction in cost of around $0.5/MMBtu.

price. The opportunity cost refers to an additional potential export of gas, which would be subject to a new contract. Thus, export prices for additional exports of gas to Jordan via the Arab Gas Pipeline were increased to $4.5/MMBtu as compared to a price for existing exports of $1.5/MMBtu (Business Studies and Analysis Center, 2009); it is reported that prices of LNG exports to France, Spain and Italy are being renegotiated to $3/MMBtu, possibly rising to $4/MMBtu in some cases (Business Studies and Analysis Center, 2009).

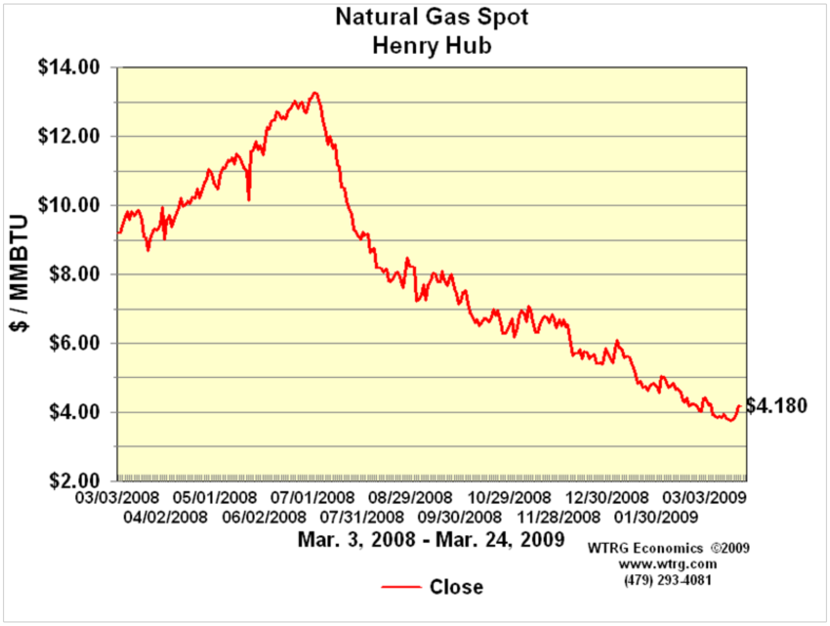
There is no single "world" price for gas. The U.S. natural gas market tends to be the most responsive to price, taking major deliveries of LNG when prices are low and eschewing them when prices are high. Within the U.S., the Henry Hub terminal in Louisiana is the most important LNG terminal and the price at this terminal is used as an indicator of the U.S. price. Gas prices rose steadily from 2000 until the summer of 2008, when they collapsed. Average LNG import prices into the U. S. rose from $3.43/MMBtu in 2000 to $9.22/MMBtu in March 2008 (IEA and OECD, 2008). Figure 6.1 shows that U.S. prices then peaked in July 2008 at over $13/MMBtu before collapsing to around $4/MMBtu in March 2009.

Applying the full costs of liquefaction detailed above[37] to world prices over the past 12 months gives an opportunity cost of Egypt's natural gas in the range $2.5/MMBtu to $11.5/MMBtu. This is clearly an extremely wide range and linking domestic prices to this opportunity cost would be challenging.[38]

[37] The lower liquefaction cost estimate from Egypt buying back natural gas committed to LNG export would increase these estimates to $3.5/MMBtu to $12.5/MMBtu.

[38] But note that tariffs to gas customers are strongly linked to world prices in countries including the U.K. and many states in the U.S.A. As consumer demand decreases, the share of infrastructure (transmission, distribution, storage, etc.) costs in final gas prices tends to increase. Thus smaller consumers (e.g. households) see their price of gas alter less when world prices change than do larger consumers (e.g. power plants and heavy industry).

Figure 6.1: US Henry Hub natural gas price, March 2008-March 2009



6.3.2 *Egyptian tariffs for natural gas*

Tariffs for gas sales to electricity generators in Egypt continue to be considerably below the bottom end of the opportunity cost range. In effect, gas to electricity generators is subsidized. This subsidy means that gas-fired power generators can sell their electricity significantly more cheaply than if they were paying the full opportunity cost of gas. This has extremely important implications for wind developers, since they must compete with artificially low electricity generation prices.

Gas prices to electricity generators were of the order of $1/MMBtu during 2006 and 2007. Increasing gas prices to electricity generators requires an increase in electricity tariffs. An October 2006 agreement between the petroleum and electricity ministries[39] planned a stepped increase in the price of gas to electricity generators from 14.1 Pt/m^3 ($0.7/MMBtu) on September 30, 2006 to 29 Pt/m^3 ($1.4/MMBtu) on October 1, 2013.

We can conclude that gas prices to electricity generators are currently of the order of $1/MMBtu and that this is significantly below the opportunity cost (which has been in the range $2.5-11.5/MMBtu since 2000). It is interesting to note that gas prices to electricity generation are significantly lower than the prices charged to energy-intensive industry, although electricity

[39] The price of 14.1 Pt/m^3 was set by Order number 776 year 1997 of the Minister of Petroleum. Increases for the period of October 1, 2006 to October 1, 2013 were approved by the Cabinet of Ministers meeting number 18 dated October 11, 2006.

generation is an intensive use of gas.[40] Increases were planned in 2008, which would have seen the price of gas outside electricity generation increased, with the largest rises being for energy-intensive industry:[41]

- Energy-intensive industry: $3/MMBtu
- Non-energy-intensive industry: $1.66/MMBtu
- Others: $1.25/MMBtu

These decisions have not yet been fully activated. The financial crisis and fluctuations in global energy prices have led to the decision to raise energy prices being postponed until the end of 2009 (Business Studies and Analysis Center, 2009).

6.3.3 Egyptian tariffs for electricity

The costs of supplying electricity tend to rise as the level of demand of the consumer decreases. Supplying electricity to individual homes and small premises requires additional distribution systems; small users also tend to have a more variable load, which means the capacity needed per unit of electricity consumed is higher; and the load profiles of small consumers are often highly correlated (e.g. consumers tend to cook at similar times of day).

Prices for electricity by consumer type for 2006–08[42] are shown in Table 6.1. Egypt's electricity prices for industry do see prices rise as the voltage level declines. However, tariffs also reflect another key Egyptian policy: prices should be relatively low for the first part of a consumer's demand and then should rise as a consumer's demand increases. Thus, from October 2007, prices were separated into Energy Intensive Industries,[43] Other Industries and Non-Energy Intensive Activities. Prices are highest to Energy Intensive Industries and the gap is increasing: price rises over the past two years have been significantly higher for Energy Intensive Industries than for other parts of Industry.[44] Recently (Feb 11, 2009), a PM decree (number 446 year 2009) reclassified some of the energy-intensive industries (glass, ceramics and chemicals) as non-intensive ones just for the year 2009 as a temporary action to partially help these industries face the worldwide financial crisis.

Prices for residential consumers follow the same pattern but are more extreme, with the first "lifeline" 50 kWh of monthly demand costing approximately $0.01/kWh (EGP 0.05/kWh). This

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[40] Note that the provision of electricity to consumers at below cost can serve social purposes, and that the removal of such low cost electricity can cause significant hardship to vulnerable members of society. For a full discussion of the issues around subsidy removal, see for example the work of the Global Subsidies Initiative at www.globalsubsidies.org.
[41] PM Decree number 1914 year 2007 and PM Decree number 1795 year 2008
[42] Collected by the authors from EEHC annual reports and www.Egyptera.org
[43] Glass, ceramics, chemicals, steel, cement, fertilizers, aluminum, copper, petrochemicals
[44] Thus for industry, Energy Intensive Industry saw increases of over 50 per cemt in tariffs between 2006–07 and 2007–08, whereas other industrial users experienced rises in the range of 8 to 17 per cent.

cost has remained stable over the past three years. In contrast, demand over 1,000 kWh/month now costs approximately $0.09/kWh (EGP 0.48/kWh). Commercial prices follow the same pattern but are somewhat higher, with prices now approximately $0.04/kWh (EGP 0.20/kWh) higher for each consumption level. Finally agricultural users pay approximately $0.02/kWh (EGP 0.10/kWh), whatever their demand.

Tariffs for electricity thus range from $0.01 to 0.10/kWh. A large share of demand is consumed by energy intensive industry, whose current tariff is approximately $0.04/kWh (EGP 0.20/kWh). Whether revenue from these tariffs, which must cover the generation costs of electricity plus its transmission, distribution and retailing, is sufficient to allow wind generators to cover their costs is a key consideration.

Table 6.1: Egyptian electricity tariffs, 2006–2008 (nominal)[45]

#	Customer classification according to the service voltage level and nature of usage			Fees related to Power factor	Oct 2006 up to Sept 2007	Oct 2007 up to Sept 2008	% Difference between 2006/07 and 2007/08 tariffs	July 2008 and Oct 2008 onwards	% Difference between 2007/08 and 2008/00 tariffs
				Tariffs (US$/kWh, using exchange rate of US$ 1 = EGP 5.5)					
1	Extra High Voltage (EHV) -500, 220, 132 kilo Volt (kV)	Energy intensive industries *		Yes	0.020	0.024	20%	0.037	52%
		Other industries **				0.022	7%	0.025	17%
		Non-energy intensive activities (industry and other users) ***						0.023	8%
2	High Voltage (HV) - 66 and 33 kilo Volt (kV)	Energy intensive industries *		Yes	0.024	0.029	20%	0.045	52%
		Other industries **				0.026	7%	0.031	17%
		Other users - non-energy intensive activities (industry and other users ***						0.029	9%
3	Housing Companies			yes	0.023	0.025	8%	no housing companies	
4	Medium Voltage (MV) and Low Voltage (LV)								
	Over 500 kW demand	Energy intensive industries *	Demand charge	yes	1.56	1.64	5%	1.89 US$/kW/month	16%
			Energy charge		0.033	0.040	20%	0.061	52%
		Other industries **	Demand charge		1.56	1.64	5%	1.73 US$/kW/month	6%
			Energy charge		0.033	0.036	8%	0.042	17%
		Other users - non-energy intensive activities (industry and other users ***	Demand charge		1.56	1.64	5%	1.73 US$/kW/month	6%
			Energy charge		0.033	0.036	8%	0.039	9%
	Up to 500 kW demand	Agriculture users		No	0.018	0.019	7%	0.020	8%
		Others		Yes	0.039	0.042	7%	0.045	8%
5	Residential users (on monthly basis)	0 – 50 kWh		No	0.009	0.009	0%	0.009	0%
		> 50 – 200 kWh			0.018	0.019	7%	0.020	3%
		> 200 – 350 kWh			0.025	0.027	10%	0.029	7%
		> 350 – 650 kWh			0.036	0.039	10%	0.044	11%
		> 650 – 1000 kWh			0.051	0.057	11%	0.071	25%
		> 1000 kWh			0.062	0.069	11%	0.087	26%
6	Commercial users (on monthly basis)	0 – 100 kWh		No	0.039	0.042	8%	0.044	5%
		> 100 – 250 kWh			0.056	0.061	8%	0.065	7%
		> 250 – 600 kWh			0.071	0.077	8%	0.084	8%
		> 600 – 1000 kWh			0.089	0.095	8%	0.105	10%
		> 1000 kWh			0.093	0.100	8%	0.109	9%
7	Offices and clinics, etc.			No	0.039	0.042	7%	0.045	8%
8	Street public lighting			No	0.065	0.070	8%	0.075	8%

[45] Note that the inflation rate in Egypt was 4.2 per cent in 2006, 11.0 per cent in 2007 and 8.8 per cent in 2008 (IMF, 2008). The exchange rate in EGP/USD was 5.79, 5.75 and 5.44 on June 30 of each year (www.oanda.com).

6.4 Costs to Egypt of wind power and alternative(s)

Costs of electricity generation can be made up of the following elements:

1. Capital costs of equipment;
2. Fuel and other operating costs;
3. Costs of connecting to the grid;
4. Incremental costs of incorporating plant into the electricity system;
5. External costs.

These items are now presented for wind and natural gas CCGT (combined cycle gas turbine).

6.4.1 *Wind power costs*

Capital costs of equipment

Wind power is a capital-intensive technology—the initial capital costs are the determinant factor of the costs of generation. The IEA (2008b) reports that wind turbine costs decreased by a factor of four between the 1980s and 2004,[46] but then increased by 20 to 80 per cent in the period of 2004–07. The increases were due to tight supply of turbines and components and high commodity prices (particularly steel and copper). In 2007, IEA figures for actual installations in OECD countries showed turbine costs in the range $1.2-1.8 million/MW and installed costs[47] ranging from $1.4–2.7 million/MW. It is understood that the latest Zafarana wind park was installed at a cost of $1.7 million/MW, including the medium voltage grid connection.

How wind capital costs will develop relative to costs of other electricity generation technologies is a key consideration. The expectation of continuing reductions in wind capital costs has not been borne out by recent experience. Major reductions in commodity prices from the peaks of summer 2008 will reduce the costs of both wind power and other generating technologies. Whether the market for wind equipment will remain tight is uncertain: almost all investment has decreased following the financial crisis; whether economic stimulus packages will be sufficient to offset these declines or even increase the market for wind is currently a matter of conjecture.

Local manufacturing of some or all of wind power systems has been mooted as a way of reducing the costs of wind. The information given below is based on a number of interviews with officials of Seweedy Wind Energy Group (SWEG), established by El-Seweedy Group (a major Egyptian conglomerate, whose major activities are the production of cables and electrical equipment).[48] The group has also expressed its interest as a developer of wind farms.

[46] With increasing turbine size being a major contributor to the cost reductions

[47] Installed costs include grid connection costs, which will clearly increase as the grid becomes more distant.

[48] http://www.elsewedycables.com

SWEG is the only Egyptian investor the authors know of that has public plans and actual investments in manufacturing wind energy generation components. Although there are market rumours and indications that other investors might be negotiating turbine and blade manufacturing facilities with international technology suppliers, none has public, definite, plans. Accordingly, none of these have yet reached a stage where production time could be estimated.

Table 6.2 shows the current and planned local manufacturing capacity. Egypt has the capability to manufacture towers and the majority of the "balance of system" items, and El-Seweedy plan to have a nacelle and enclosed turbine capacity by early 2010. Together, these account for around 75 per cent of the investment costs of wind. El-Seweedy officials, in personal communications to the paper authors, estimate that using locally-manufactured components to the full extent possible could reduce system costs by 10–15 per cent in the short term, possibly increasing to 25 per cent in the longer term as the local supply chain is better integrated.

Table 6.2: Current and planned capacity for system manufacture in Egypt

Component	Share of Wind Investment Costs	Egyptian Capability
Towers	15 per cent	A number of manufacturers have the capacity and have supplied certain donor-financed schemes. El-Seweedy and the German tower manufacturer SIAG have established a joint venture that plans to be able to supply the market by the end of 2009, with an eventual planned capacity of 400 towers/year. The sheet steel needs to be imported—there is no current Egyptian capacity, nor any planned.
Nacelle and enclosed turbine	40 per cent	El-Seweedy have bought a stake in Spanish company M. Torres to ease technology and experience transfer. Egypt's facility (in 10th of Ramadan) is expected to supply the market from early 2010.
Blades and Rotor	20 per cent - blades main component	No public plans announced as yet. El-Seweedy group has ongoing negotiations with potential international partners.
Balance of the System	25 per cent	Egyptian capacity to deliver is good. There is a large network of qualified contractors. Local cable production includes exports. Transformer manufacture is well-rooted. Some other components (for example certain electronic components) are not available locally.

Import tariffs

According to current Custom tariffs,[49] "equipment and components as well as spare parts of new and renewable energies (wind and solar energy) are subject to 2 per cent custom tax of value." The article adds that conditions will be applied, according to a decree issued by the Minister of Finance. It appears that this decree has not yet been issued and that current practice is that importers must request that the 2 per cent tariff is applied to their imports on a case-by-case basis; it is understood that this request is generally approved. The issuance of the decree would make the procedure smoother.

It is important to note that the 2 per cent tariff only applies to "specific" components and that "non-specific" components such as batteries, cables, etc., would be excluded. Egypt's bound and applied tariffs for the HS codes covering the main components of wind turbines are shown in Table 6.3 (WTO, n.d.). Of note is the 30 per cent average tariff that is applied to the import of towers, which can be considered a "non-specific" component of a wind installation.

Table 6.3: Import tariffs for wind equipment

HS Code	Description	Wind power component	Bound tariff[50]	Applied tariff
841290	Parts of engines and motors, n.e.s.	Turbine Blades	20 per cent	2 per cent
848340	Gears and gearing for machinery, incl. speed changers and torque converters, ball and roll screws	Gearbox	30 per cent	5 per cent
850161-64	AC generators "alternators" [various outputs]	Generator	20 per cent	5 per cent
848210-50, 80	Ball bearings and roller bearings	Bearings	10 per cent	5 per cent
730820	Towers and lattice masts of iron or steel	Tower	40 per cent	30 per cent
853720	Boards, cabinets and similar combinations of apparatus for electric control or the distribution of electricity, for a voltage > 1.000 V	Control Equipment	45 per cent	10 per cent

Operating costs

The IEA (2008b) reports the annual operating cost for large onshore turbines in the OECD is USD$14-26/MWh. These costs include insurance, regular maintenance, spare parts, repair and administration. The Royal Academy of Engineering's respected 2004 study on the costs of electricity generation indicated a cost of 0.9 pence/kWh (USD$15/MWh) at a load factor of 35 per cent.

[49] Article 5 of Presidential Decree 39/2007 on Custom tariffs

[50] Bound tariffs represent commitments made by countries, under World Trade Organisation agreements, not to raise tariffs on specific items above a specified level. They thus represent an upper limit

Capacity factors for wind are typically in the range of 25–40 per cent. Egypt's excellent wind resource means that its load factors can be at the top of, or above, this range. Electricity production from Zafarana is quoted as having an a capacity factor of 40.6 per cent (Greenpeace, *et al.,* 2008); the three CDM projects within the UNEP Risoe CDM/JI Pipeline show planned capacity factors of 50.0 per cent, 42.8 per cent and 38.0 per cent—a simple average of 43.6 per cent.

Egypt's high capacity factor, and the relatively low cost of local labour and services, suggests that operating costs for wind will be low in international terms. A figure of USD$8–12/MWh is indicated.

Costs of connecting to the grid[51]
All generating technologies need to be connected to the grid. Costs are highest when a plant is furthest from the existing grid, when the upstream grid needs strengthening in order to take the new power generated and when the capacity factor is low. Although actual costs are highly case-specific, wind power connection costs per unit of electricity generated tend to be higher than for natural gas or other "conventional" fuels.

Incremental costs of incorporating plants into the electricity system
Wind power is variable and this imposes additional costs to generating electricity when compared to less variable sources. This variation is highest for single wind farms but decreases as the number of wind farms increases, particularly if there is a geographical spread.[52]

Estimating incremental costs due to wind's variability is system-specific. They also depend strongly on the share of wind in the system's generating mix: in general, costs increase as the share of wind in the electricity mix increases. Additionally, many commentators state that a step change in extra costs will be experienced when some threshold share of wind capacity is exceeded. An often-quoted figure is 20 per cent, but this has a somewhat arbitrary nature (Greenpeace, *et al.,* 2008, p. 26).

It is important that comparisons among options are made on a like-for-like basis. If a new CCGT plant were constructed, its relatively low marginal generation costs in comparison to existing gas and oil plants on the system would mean it would tend to be run as a base-load plant, that is, at high load factor. The existing gas and oil plants would tend to move up the "merit order," being used at lower load factors than before the new CCGT plant was constructed. A new wind plant would also be run as base-load plant, but with the important distinction that wind generation is not as reliable as that of gas. More reserve plants would thus be needed to be maintained on the system, which would increase costs relative to the new gas CCGT option. Calculating the difference in costs is an

[51] More detailed figures are available on a case-by-case basis from NREA.
[52] See for example Greenpeace, *et al.* (2008), which discusses how a single wind farm can exhibit 60 per cent output variability hour by hour (p. 25), but across all wind farms in Scandinavia variations are of the order of 10 per cent.

involved process, requiring detailed, system-specific modelling. For this study, a simpler approach is taken: generic figures are taken from referenced sources. Thus, the European Wind Energy Association states that, "the additional balancing costs associated with large-scale wind integration tend to amount to less than 10 per cent of wind power generation costs," (EWEA, forthcoming 2009) quoting case studies from countries and regions including Spain and Germany.

External costs

A wide range of external costs from wind power and alternatives could be included. The most important of these tend to be gaseous pollutants of greenhouse gases, acidic gases and particulates. The analysis within this paper includes an assessment of CO_2 only, assuming that the damage costs can be calculated using the market price of carbon credits.

6.4.2 *Natural gas CCGT costs*

Operating costs, themselves dominated by fuel costs, dominate the costs of generation from natural gas CCGT. Its capital costs are relatively low per unit of capacity and per unit of electricity generation. Capital cost estimates tend to be of the order of $500/kW with non-fuel operating costs of the order of $5/MWh and a capacity factor of 90 per cent.[53]

The key determinant of generating costs is the cost of gas purchased.[54] With a typical efficiency of a new gas CCGT plant being of the order of 55 per cent, each unit of electricity generated requires approximately two units of gas input. Making this initial calculation will rapidly give an indication of the marginal costs of electricity generation within a system.

6.5 Comparison of the costs of generation of wind to alternative(s)

6.5.1 *Comparison using cost estimates from the previous section*

Table 6.4 summarizes the data presented in Section 6.4; gas costs are added in at a variable gas price and a constant 55 per cent generation efficiency. It is important to note that the figures presented are subject to a range of assumptions and uncertainties, and thus have the characteristic of a single "point" estimate within a range. Sensitivity analysis against the main assumptions is presented in Section 6.5.3.

Levelized costs are calculated, based on a 10 per cent discount rate applied over a 20 year period.[55] No extra costs are ascribed to wind's extra connection costs; nor are any external costs applied to gas generation. No value has been ascribed to the land needed to site either scheme and costs are

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[53] See for example Royal Academy of Engineering, 2004.
[54] It is typically of the order of 70 per cent.
[55] IEA (2008b) reports that the estimated lifetime of an individual wind turbine is 20–25 years; reliability is high, with technical availability typically around 99 per cent.

free of import or other tariffs. Finally, no account has been taken of the varying value of electricity over time: this value is higher at times of peak load (e.g. during the summer). There is a view that wind output, to some extent, matches periods of peak load.

Figure 6.2 plots the levelized costs of generation of wind and gas, as a function of the gas price. The figure shows:

- wind generation costs without carbon credit[56] are UScent 6.2/kWh. This is more expensive than gas generation until the gas price reaches $8/MMBtu;
- with a carbon credit of $20/t$CO_2$, the break-even point is at a gas price of $7/MMBtu;
- with a carbon credit of $50/t$CO_2$, the break-even point reduces to $5/MMBtu.

All three break-even points are considerably higher than the current gas price in Egypt of $1/MMBtu. The gas opportunity cost was calculated earlier as $2.5–11.5/MMBtu, based on gas prices of the last ten years. At the mid-point of this range ($7/MMBtu), wind and gas generation costs are comparable when a carbon credit of $20/t$CO_2$ is included.

Table 6.4: Comparison of costs of electricity generation from wind and natural gas CCGT

	Wind	Gas	
Discount Rate	10%	10%	
Economic Lifetime	20	20	years
Capital cost (installed)	1500	500	$/kW
Levelised capital cost	176	59	$/kW/year
Capacity Factor	43.6%	90%	
Levelised capital cost	4.61	0.74	cents/kWh
Non-fuel O&M	1.00	0.50	cents/kWh
Total	5.61	1.24	cents/kWh
Balancing	0.56	-	cents/kWh
Total inc. Balancing	**6.17**	**1.24**	**cents/kWh**
Generation Efficiency	n/a	55%	
Carbon Credit @ $20/t$CO_2$	0.73		cents/kWh
Carbon Credit @ $50/t$CO_2$	1.82		cents/kWh

56 Note that it would be more economically efficient to impose a carbon cost on emissions of greenhouse gases (GHGs) rather than give carbon credits to options that do not emit GHGs. For the purposes of the comparison made between natural gas and wind in this paper, there is no practical difference between the two options.

6.5.2 Other estimates of the costs of generation in Egypt

Natural gas

The Egyptian Electricity Transmission Company (EETC) is the single buyer of electricity in Egypt. Its 2007–08 Annual Report quoted an average selling price from thermal generators of 10.5 Pt/kWh (UScent 2/kWh). This is similar to the contracts given to the three privately-financed CCGT plants built in Egypt in the 1990s: the agreed purchase power agreement was for UScent 2.34/kWh, with changes in gas price, exchange rate and taxes all to be made good by the Egyptian state (ERM and Environics, 2003). These electricity generation prices are in line with gas prices to electricity generators of the order of $1.5/MMBtu.

Wind

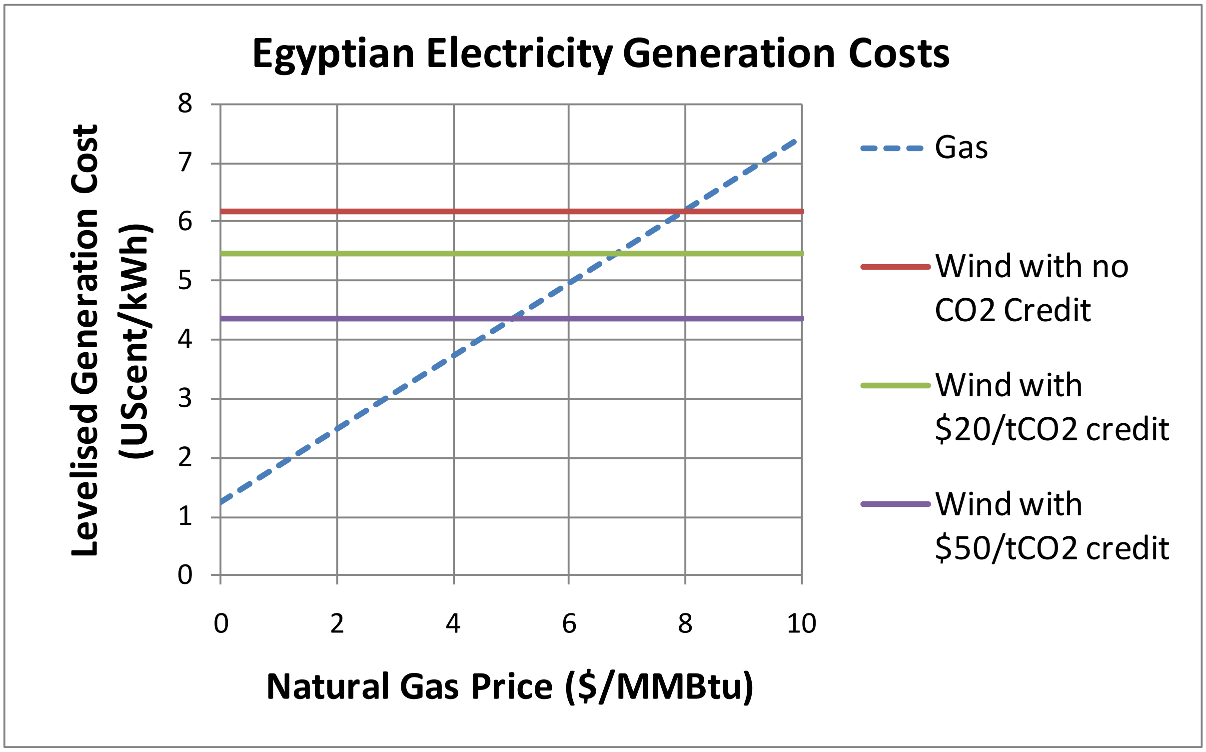
Figure 6.2 estimated costs of wind generation in Egypt to be of the order of UScent 6/kWh (i.e 34 Pt/kWh). This figure is of a similar order of magnitude to NREA estimates of the costs of wind generation of Euro cent 5.5/kWh.[57] The 2008 Global Wind Energy Outlook gives generic figures of UScent 4–6/kWh at high wind speed sites up to approximately UScent 6–9/kWh at sites with lower average wind speeds (Greenpeace, 2008, p. 43).

These generation costs far exceed the prices currently paid to wind generators in Egypt. Current prices (EEHC, 2008b) are 12.6 Pt/kWh (with an annual increase of 5 per cent) plus 2 Pt/kWh from the petroleum ministry for the fuel savings, a total of around UScent 2.5/kWh. CDM credits are also generated by the later schemes, adding of the order of UScent 0.5-1/kWh. The total revenue is significantly below costs and the difference is made good by the Government of Egypt.[58]

[57] From a number of presentations by NREA in 2007. At an exchange rate of €1=US$1.3, the generating cost is of the order of UScent 7/kWh. The estimate is based on commercial financial terms but does not consider the cost of land or its leasing.

[58] Note that donor finance of wind power developments in Egypt to date typically cover a large part, but not all, of the difference between wind plant costs and revenues.

Figure 6.2: Levelized costs of electricity generation from wind and natural gas CCGT



6.5.3 Sensitivity analysis

The analysis presented in Section 6.5.1 was described as a point estimate within a range of possibilities. Four of the key variables that would alter the relative economics of wind against gas are the:

1. load factor of wind;
2. capital cost of wind;
3. capital cost of gas;
4. discount rate used by investors.

Table 6.5 summarizes how the break-even gas price (the price where gas and wind generation is equal) changes when these four variables are independently increased or decreased by 25 per cent. The economics of wind are most adversely affected by a reduction in the load factor, although a reduction in the estimated wind resource of 25 per cent would be considered unlikely if a new site had properly assessed historical data. The figure is more useful to compare sites where the wind potential is 25 per cent lower than the best sites.

The capital cost of natural gas has little effect as it is a relatively small component of the levelized cost of gas generation. Were wind capital costs to be 25 per cent lower than the $1500/kW assumed in the "base case," the break-even gas price would be reduced by approximately $2/MMBtu, making wind considerably more financially attractive. Conversely, a 25 per cent increase in capital cost estimates would add approximately $2/MMBtu to the break-even gas price.

The importance of reducing capital payments for wind is further illustrated by the discount rate sensitivities. An increase in the discount rate of 25 per cent (from 10 per cent in the "base case" to 12.5 per cent) has almost as much impact as increasing the capital cost of wind by 25 per cent. What discount rate investors would use is a function of risk, and this is not fixed. Government policies and regulations to reduce risks will lower the cost of capital to wind and will improve its economics.

Table 6.5: Comparison of costs of electricity generation from wind and natural gas CCGT

Break-even gas price, $/MMBtu	Wind with no CO_2 credit	Wind with $20/t$CO_2$ credit	Wind with $50/t$CO_2$ credit
Wind load factor -25%	10.7	9.5	7.7
Wind capital cost +25%	9.8	8.6	6.9
Discount Rate +25%	9.4	8.2	6.5
Gas capital cost -25%	8.2	7.1	5.3
Base Case	**7.9**	**6.8**	**5.0**
Gas capital cost +25%	7.6	6.5	4.7
Discount Rate -25%	6.6	5.4	3.7
Wind load factor +25%	6.3	5.1	3.4
Wind capital cost -25%	6.1	4.9	3.2

6.5.4 *Tariff-setting in Egypt: Current arrangements*

Wind generation has traditionally been considered as being:

- uncompetitive (high investment cost, especially when considering the additional capacity needed due to wind's low capacity factor);
- an inefficient source of energy for electricity production, given that Egypt has sufficient oil and natural gas resources to cover its forecasted needs for electricity;
- a non-despatchable generator of electricity.

Current tariffs paid to wind generators are referenced from the viewpoint of a single buyer model (EETC buys 99 per cent of current electricity generated). Tariffs within the model were designed with the target of achieving positive returns for electric generation, transmission and distribution utilities, ideally equal for each organization. The procurement prices of electricity from electricity wind farms were not set based on financial cost of service analysis; rather, they were set in comparison with the cost of electricity generation from thermal power stations (which in turn were based on fuel purchases significantly below opportunity cost). Wind producers thus received a payment based on the value of a subsidized avoided fuel cost.

Current electricity tariffs to final consumers average around UScent 4/kWh (see Section 6.3.3). The cost from wind generation alone is higher than this tariff. The tariff also needs to cover the costs of electricity generation, transmission, distribution and retail.[59] If electricity tariffs are to be maintained at their current levels and part of the revenue from these tariffs is needed to finance the transmission, distribution and retailing of electricity, then any source of electricity generation would need to be subsidized. At present, this is achieved by setting natural gas prices to electricity generators below their opportunity cost.

[59] Current proposed costs for using the transmission and distribution system are around 8 Pt/kWh, or UScent 1.5/kWh (the cost for the use of distribution networks is not quite final yet).

7.0 Necessary Conditions for Large-Scale Implementation of Wind in Egypt

7.1 Overview

Egypt has ambitious plans to scale-up its wind capacity. Investments to date have been supported by the Egyptian state with support from foreign donors; later schemes have also been registered under the Clean Development Mechanism. In order to meet its plans, there needs to be a step change in the scale of annual investments: Egypt expects the private sector to be the source of this investment.

Egypt has some of the conditions necessary for large-scale of implementation in place: its knowledge infrastructure is well-developed (notably the state-of-the-art wind atlas); it has many years of successful experience operating wind farms; there is serious technical discussion taking place around electricity plan transmission from the Gulf of Suez focus area; and there is private sector interest in investing in wind schemes and in local manufacturing of some of their components. Other necessary conditions are partially covered, are planned or are missing. This paper identifies five necessary conditions that are needed going forward:

1. A clear statement of why Egypt wishes to support wind power;
2. A clear statement of the strategy Egypt will follow to build up its wind capacity;
3. Setting the tariff that wind power should receive, and how this may change over time;
4. A plan identifying how investments in grid connections and strengthening will be realized;
5. Identification of the role NREA and other state organizations will play, and how this can encourage private sector participation.

7.2 Five necessary conditions

7.2.1 A clear statement of why Egypt wishes to support wind power

Renewable power is not an end in itself: its attraction is the benefits it brings. These benefits include: freeing up gas for export; increased energy security of supply; increased resistance to future fossil fuel price shocks; lower emissions of greenhouse gases and other pollutants; and the possibility to build up new local industry.

There does not appear to be a consensus on the benefits of wind power within Egypt. Current prices for electricity sale to the grid recognize only the avoided cost of the gas displaced, and then only from the perspective of the electricity utility rather than the full opportunity cost to Egypt. On the other hand, the ambitious plans for wind indicate Egyptian recognition of the wider benefits wind power brings.

The development of a clear statement of why Egypt wishes to support wind power would allow government departments to discuss the key benefits. The achievement of a consensus view across government would considerably aid the development of a comprehensive, enabling policy and regulatory environment.

7.2.2 A clear statement of the long-term strategy Egypt will follow to build up its wind capacity

Once the benefits of wind have been agreed upon, Egypt needs to better define its strategy in building up its wind capacity. This strategy needs to define the following:

- *The phases of the capacity build-up.* Egypt's wind program to date has essentially been one of demonstration. Two further phases could be identified: (i) a technology development phase, within which relatively high levels of support are given to wind power in the expectation that this would lead to cost reductions for later wind installations. Such support is indicated in countries that develop their own technologies, of which Egypt is not currently one; (ii) an implementation phase, based on what is considered to be a fully-commercialized technology. It is not clear whether there is still the possibility of a technology development phase, either world-wide and/or in Egypt. If there is not, support should be based on reasonable technology forecasts, which will not necessarily imply large decreases in costs over time.
- *The location and size of future wind farms.* The Gulf of Suez is identified as Egypt's best location but there may be advantages[60] in also developing other sites. Whether new schemes should be relatively small (250 MW) or large (2,500 MW) is an important consideration and one further studies would shed light on.
- *The roles private and public sector capital will play in future investments.* Egypt's future plans envisage the public sector continuing to make investments until 2012 and then the private sector supplying investment from 2013. This plan deserves further consideration—a partnership between the public and private sectors may be preferable in at least some schemes.
- *Whether Egypt wishes to build up local manufacturing capacity.* Local manufacturing could bring a range of benefits, including local jobs and technological expertise, improvements in the balance of trade and resistance to supply shortages in the world market. China and India are now among the leading generators of wind power; both ensured that the build up of capacity also led to the build up of their own manufacturing industries (DFID, 2008, Section 4.4). Conversely, New Zealand decided that it would be more cost-effective to build up its

[60] Notably, the possibility of lower costs of incorporating wind from these sites into the electricity system and the general benefits of diversity.

capacity using imported equipment. Much of the Egypt's first wind farm (the 5.2 MW Hurghada installation) used locally manufactured equipment; some blade and mast components are already made in Egypt and more could be. An Egyptian investor has invested (30 per cent) in a Spanish company making gears for wind gearboxes. Perhaps the key question is whether Egypt wishes to get "ahead of the game" and build up its industry in advance of the major capacity expansions planned. Egypt's import tariffs are currently low but raising these, while being supportive of local manufacturers, would also raise prices for equipment in Egypt.

The strategy should aim to provide investors with the long-term certainty they desire when considering investments with high up-front costs.

7.2.3 Setting the tariff that wind power should receive, and how this may change over time

General principles

There is no shortage of potential investors in the wind sector in Egypt. Many of these are local, or include Egyptian partners. However, the current prices paid for electricity are not sufficient to allow these investors to cover their costs.

Section 6 concluded that whether wind was competitive with gas depended primarily on the world price of gas, which has varied over a wide range over both the last 12 months and the past 10 years. Using the gas spot price as the basis for the value of wind power would thus lead to a highly variable tariff to wind generators. Further uncertainties in the calculation of the "correct" gas price are introduced during the calculations of what the "world" gas price should be and of Egypt's opportunity cost of gas.

Wind power investments are capital-intensive and require a significant period for their payback: investors require a level of certainty and consistency as to the revenues they will receive over this period.[61] Setting the optimal tariff for wind power generators requires account to be taken of the opportunity cost of gas and a valuation of the other benefits that wind power brings to Egypt (see Section 7.2.1). If investments now will lower wind generation costs in the future (see Section 7.2.2), a higher tariff could be applied, although this should be phased out over a defined period.

A fundamental question to be answered is whether the Government of Egypt should contribute to the costs of wind schemes that are not commercially viable. Whilst Egypt has an interest in seeing the prices of wind turbines decrease and in reducing emissions of greenhouse gases, it is not obvious that it should pay some or all of the incremental costs of wind generation. Egypt could argue that it is foreign investors who should cover the incremental costs, for example by extending the reach of

[61] The IEA is assessing the effectiveness of renewable energy policies in its ongoing Global Renewable Energy Markets and Policies Analysis Programme (as reported in IEA, 2008a).

renewable credits schemes to allow Egyptian renewable generators to receive the same benefits as European generators (noting that such certificates reach prices typically of the order of UScent 5/kWh). On the other hand, Egypt would gain other benefits from increasing its share of wind power, for example increased security of supply, lower levels of local air pollution and potential macro-economic benefits from local manufacturing.

Egypt's proposed New Electricity Law[62]

The proposed New Electricity Law is under development and is expected to go before parliament within the year 2009–10. It may serve as an important step in the development of wind power, but there are a number of issues that need to be considered in more detail.

Current tariff-setting principles do not allow wind power to recover its costs. Ideally, final consumer tariffs would be raised to reflect full costs, allowing gas to be priced at opportunity costs and fair competition between all electricity generating options. Even if this is not possible, an indirect scheme that allowed the costs and benefits of alternatives to be compared on a fair basis could be implemented.

Chapter 4, Section 1 of the proposed electricity law addresses renewable energy over five articles (45–49). The proposals could have a major impact on the development of wind power. They include four major provisions:

1. *Competitive tenders for the construction of wind farms to be operated by NREA or EETC.* Article 45 states that the Egyptian Electricity Transmission Company (EETC) could conduct Requests for Quotation (RFQ) for the construction of wind farms, which it would then operate, selling the electricity to EETC at a price proposed by the regulatory agency and agreed by the Cabinet of Ministers. Tenderers who can point to local production of some or all components of the wind system will receive additional points under the planned tender evaluation process. This process remains under development: two experts (one legal, one technical) from the World Bank have been developing the process, with a first planned step being a consultation workshop with those who have expressed interest in investing in wind capacity. Public consultation on the mobilization of existing resources and attraction of others was held. Box 7.1 summarizes progress on the process up to mid-August 2009.
2. *Take-or-pay contracts for renewable electricity generation, governed by long-term purchase power agreements (PPAs).* Article 45 allows for any investor to build, own and operate a renewable power plant, selling the electricity to EETC at a generic price announced by the cabinet of ministers. This price would be governed by a 15-year power purchase agreement. If EETC does not wish to take the electricity generated, they would still have to pay for it.

[62] The draft final version of the law was approved by the State Council (the highest legal authority in Egypt) and should be discussed shortly in the Parliament.

3. *EETC will be responsible for connecting new renewable schemes to the grid.* Article 46 states that the licensed transmission and distribution utilities are obliged to interconnect their networks with renewable electricity generating stations and to cover the corresponding investment needed for strengthening their networks.
4. *A special fund will be established to help pay for electricity generated from renewable schemes—"The Fund for development of electricity production from renewable energies."* Articles 47–49 state that, under the cabinet of ministers, this fund would provide support to EETC to buy available electricity from renewable generators. The fund would be financed by: (a) savings due to avoided gas and oil purchases by thermal generators; (b) grants, donations and contributions; and (c) the fund's returns on its investments.

Box 7.1: Progress on Egypt's RFPQ for a wind power development in the Gulf of Suez to mid-August 2009

In May 2009, the Egyptian Electricity Transmission Company issued a Request or Prequalification (RFPQ) for the development of a 250 MW BOO Wind Power Project at the Gulf of Suez in Egypt. The main issues were:

- It invited IPPs/developers/wind turbine manufacturers to submit their prequalification to build, own and operate (BOO) a 250 MW wind power plant; and to be operational by December 2013.
- Bidders with experience of 50 MW or higher wind farms (BOO, BOOT) projects are the ones allowed to bid.
- This project is the first and others will follow (an overall time plan up to year 2020 was indicated for an overall capacity of 5,000 MW through the private sector; NREA's more detailed plan was included).
- The RFPQ process will conclude with a short list of potential candidates (over 60 entities showed interest and bought the RFPQ documents; around 30 entities submitted their proposals).
- Bidder's consortiums are allowed, with clear assignment for each member of the consortium.
- The shortlisted bidders will be given a 12-month access for site wind measurements either individually or collectively through a creditable agreed-upon entity.
- The shortlisted bidders will be invited to submit their proposals through a request of proposals (RFP). The RFP will be issued three months prior to the end of the wind measurement phase.
- The RFP will include, among other items:
    - A draft land lease agreement (Usufruct Agreement)
    - A 20–25 years power purchase agreement (PPA)
    - A guarantee from the central bank of Egypt
- The involvement of a number of the World Bank agencies and programs were indicated, especially for the second phase (which will include bid evaluation, contract negation and financial closure).
- A 1,000-point scoring system will be used for evaluating the bids as follows:

Item	Points
General format and completeness	50
Introduction	50
Project approach	100
Qualification and experience	450
Human Resources (general & project team)	150
Financial resources	150
Conduction resources	50

- Also, it was indicated that the RFP may include bonus points for the local content; on the other hand nothing was mentioned in the RFPQ regarding local involvement.

Setting tariffs using the proposed New Electricity Law

The proposed New Electricity Law could provide the basis for the large-scale implementation of wind power, but a number of issues need to be resolved and further detail added.

It seems clear that gas prices will not be raised to the level of their opportunity cost within the near future. Nevertheless the proposed law gives the potential to set a price based on a long-term economic vision, considering the full economic costs of wind and gas generation and the costs of providing the necessary electricity system to incorporate power from the two options. The key principle for the analysis is the economic cost to Egypt: transfer payments based on details of actual wheeling and feed-in tariffs are a secondary consideration.

The proposed law states that PPAs will be set with fixed prices. This has some similarities with feed-in tariff schemes, the main difference being that it can be expected that the Egyptian scheme would result in different prices for different sites.

Many issues need to be resolved in connection with a tender or a series of tenders for wind concessions in Egypt. It is understood that large international wind turbine manufacturers expressed a preference for a fixed tariff scheme in discussions with the Government of Egypt. However, fixed tariff schemes are, in principle, open-ended in terms of volume of megawatts. If the Egyptian authorities set a fixed price, it is far from obvious how to control the volume of investment, how to plan for reinforcement of the grid, how to ensure efficient allocation of the best land without risking developers blocking the best sites without de facto investing, ensuring an adequate critical mass for turbine manufacturers to invest in local manufacturing of components, etc.

Green certificates (and feed-in tariff schemes that offer the same tariff to all sites) would give excess rent to wind developers who capture the best sites. Certain variants are imaginable, for example, setting differentiated tariffs according to the quality of the wind resource, tendering for a fixed kWh price but with competition on annual concession fees (which would effectively mean that the fixed tariff becomes an upper bound for prices), etc. There may also be wake effects caused by upstream wind farms on those downstream; again, a provision in the contractual conditions is indicated here. Feed-in tariff design does offer the possibility of differentiating remuneration across sites.

Another consideration will be whether the Government of Egypt or the electricity customers should bear the wind resource risk. Egypt has de facto conducted a substantial amount of pre-development of the key wind sites, which reduces one of the risks faced by independent power producers (IPPs).

Finally, no time frame is given for actions under the law.[63] In a more mature development phase (when the transition between public sector and private sector investment has been completed), conditions may need to be amended or added to reflect the needs of more experienced investors within a larger market for wind power.

It is difficult to draw definite conclusions as to whether feed-in tariffs, green certificates or site concessions are the best scheme for Egypt; each has its pros and cons. The current approach, envisaging site-by-site concessions following competitive tender, has considerable merits, in that it will allow Egypt to discover what price it needs to pay the private sector to develop wind schemes and it will allow Egypt to build up its knowledge over a planned series of site developments. On the

[63] Although such time frames and other details may be better dealt with in an implementation plan

downside, competitive systems only work if they are genuinely competitive (if the number of active players is low, there will be opportunities for gaming and/or collusion); the proposed scheme also focuses only on supply, and thus does not involve consumers in the choice as to whether they wish to buy electricity generated from wind and at what price.

Egypt's current approach would allow feed-in tariffs to be set more precisely at a later date if required, although it should be noted that feed-in tariff schemes to date have generally not been used for schemes with over 50 MW of capacity. Many countries have already adopted feed-in tariffs, with the IEA (2008a) commenting, "feed-in tariffs have generally been more effective than tradable green certificate-based schemes in developing renewable energy technologies." They add that this has been achieved "at a relatively high price," but this is not a universal view: other studies tend to show that the costs to society are lower under feed-in tariffs. The principal reason given is that there is lower regulatory risk compared to uncertain green certificate prices and they are thus willing to offer capital at lower costs.

7.2.4 A Plan identifying how investments in grid connections and strengthening will be realized

The proposed New Electricity Law states that it will be the state-owned transmission and distribution (T&D) utilities that will construct and finance new connections and strengthen the grid as required. International experience has shown that such connections and strengthening can become a major bottleneck and that rules must be very clear on who is responsible for doing what, what principles and rules they must follow, and when activities must be started and completed. Many supporters of renewables have claimed that T&D utilities have acted against the interests of new renewable generators.

The first consideration concerns system planning. There is a major difference between renewable developments concentrated in a single area (e.g. the Gulf of Suez) and a number of smaller, more dispersed sites. It is unreasonable to expect T&D utilities to have no say as to where developments should be located or their relative costs. Studies of a range of scenarios are indicated.

The second consideration is financing. It is straightforward to state that T&D utilities should finance connections and grid strengthening. It is much harder for these utilities to find the necessary investment capital, particularly in times of rapid expansion of the electricity system. A possible compromise position, used in several countries including the U.K., is to require new renewable generators to pay for the upfront costs of connections and strengthening, with repayment then being made over a relatively long period. In effect, the renewable generator provides a loan: this is a major commitment, and thus acts to disincentivize those who may not be fully committed to generating electricity over the long term. In the UK, the scheme was found to act as a barrier to investment as renewable investors found it harder to raise capital than the transmission operator: it was replaced by shallow charging.

7.2.5 Identification of the role NREA and other state organizations will play, and how this can encourage private sector participation

Section 7.2.3 discussed the possibility of NREA and EETC contracting the construction of renewables under the proposed New Electricity Law. NREA and EETC already have a range of responsibilities within the Egyptian electricity sector and the proposed law would amend and, in some cases, extend these.

According to Egypt's plans, the first private sector wind farm would come online in 2013. However, there are still two options for the future beyond 2013: all private sector, or part NREA. In principle, a decision needs to be taken concerning whether public-sponsored investments will continue for the longer term. This is partly an ideological decision, but can be guided by analysis. The role of NREA needs to be clarified. There is a clear need to separate its planning and operation functions; this could be achieved by splitting the organization into planning and operating agencies. NREA could sell its existing assets to the private sector, perhaps following the precedent of the Egypt's first mobile telephone network. A compromise position could be with NREA acting as a standard partner within all wind developments, in line with the roles played by EGPC in the oil sector and EGAS in the natural gas sector.

Capacity-building activities could assist the development of wind in Egypt. Specific training is needed to improve local capacity in construction, operation and maintenance, and civil, electrical and mechanical engineering. A serious undergraduate introductory course should be introduced in relevant schools of Egyptian universities as soon as possible, with a post-graduate diploma established in cooperation with NREA. Current local capacity is concentrated within NREA; private developers have an interest in developing the pool of local talent but will be concerned not to develop staff for their competitors. Finally, the CDM has been used for three wind projects to date in Egypt. Streamlining procedures, particularly those related to the Designated National Authority (DNA), may assist with the aim of accessing private investment, sourced as widely as possible.

8.0 Conclusions and Recommendations

8.1 Conditions necessary for a large-scale implementation of wind power in the future

This case study is designed to demonstrate the issues around encouraging significant clean energy investment within fossil-fuel rich, developing countries. It has:

- described the development of wind generation to date, within the context of the development of the energy and electricity sectors;
- analyzed the factors supporting and constraining investment—what these have been to date and how they might develop in the future; and
- discussed the conditions that would be necessary for a large-scale implementation of wind power in the future.

This case study finds that the principal barrier to the large-scale implementation of wind power is the low price paid for wind generation under current arrangements. This low price is itself a function of the Egyptian tariff system: final consumers of electricity pay relatively low prices, which require natural gas prices paid by electricity generators to be held significantly below the opportunity cost Egypt could realize by exporting the gas as LNG.

Egypt has some of the conditions necessary for large-scale of implementation in place while others are partially covered, are planned or are missing. Five necessary conditions for the large-scale implementation have been identified:

1. A clear statement of why Egypt wishes to support wind power;
2. A clear statement of the long-term strategy Egypt will follow to build up its wind capacity;
3. Setting the tariff that wind power should receive, and how this may change over time;
4. A plan identifying how investments in grid connections and strengthening will be realized;
5. Identification of the role NREA and other state organizations will play, and how this can encourage private sector participation.

Fulfilling these conditions will require a range of further work covering technical, political and regulatory activities. Perhaps the key amongst these will be a discussion of what benefits wind power could bring to Egypt and thus what price it, alone or with contributions from abroad, would be willing to pay for it. This calculation takes place within the context of highly volatile world gas prices but must provide sufficient certainty for private sector investors to commit to what is a long-term investment.

8.2 Further work

This case study provides useful information for those interested in developing wind plants in Egypt. Such information was found to be relatively dispersed and there was no single point where it could be obtained. The case study could in the future be further expanded into a *Handbook for Wind Developers in Egypt*. It would require the addition of extra sections, notably a more detailed guide to the relevant regulations and policies and more site-specific information.

The authors intend to update this case study on a regular basis, whenever a major update and/or change (financial, economical, legislative, etc.) takes place within the Egyptian energy market or elsewhere.

Looking more widely, calculating a fair price for wind in Egypt appears to be a key piece of missing information from the point of view of the government. More widely still, the debate on the merits and disadvantages of a major expansion in North African renewable capacity and its export to Europe would benefit from detailed considerations of the cost of expanding grids in countries including Egypt and how the most effective trading arrangements could be set up (for example, it may be beneficial to consume renewable generated electricity in Egypt and export natural gas to Europe).

References

3 Tier. (n.d.). REmapping the World. Retrieved November 2009 from: http://www.remappingtheworld.com.

BP. (2008) *Statistical Review of World Energy 2008*. Retrieved November 23, 2009 from: http://www.bp.com/multipleimagesection.do?categoryId=9023755&contentId=7044552.

Business Studies & Analysis Center. (2009, March). *Petroleum Sector Developments in Egypt*. Egypt: American Chamber of Commerce in Egypt.

Decon/Fichtner. (2008, January). Feasibility Study for a Large Wind Farm (3,000 MW) at Gulf of El-Zayt. Egypt: Decon/Fitchner.

Egyptian Electricity Holding Company. (EEHC). (2008a). Annual Report 2007–08. Retrieved November 2009 from: http://www.egelec.com.

Egyptian Electric Holding Company. (2008b). Annual Technical, Commercial and Financial Report 2007. (Limited circulation). Egypt: EEHC.

Egyptian Electric Regulatory Agency. (n.d.). Retrieved November 2009 from: www.egyptera.org.

ERM and Environics. (2003). *Energy-Environment Review 2003*. Egypt: World Bamk.

European Wind Energy Association (EWEA). (2009, forthcoming). *Wind Energy – The Facts, Volume 2*. Belgium: EWEA.

Fahmy, S. (2000) http://www.ngv2006.com/data-NaturalGas industryinEgypt.htm.

Greenpeace, Global Wind Energy Council and Wind Power Works. (2008, October). *Global Wind Energy Outlook 2008*. Retrieved November 2009 from: http://www.gwec.net/fileadmin/documents/Publications/GWEO_2008_final.pdf.

IEA. (2005). *World Energy Outlook 2005: Special Issue on Middle East and North Africa Insights*. Paris: IEA.

IEA. (2006a). *Electricity/Heat in Egypt for 2006*. Retrieved November 2009 from: http://www.iea.org/Textbase/stats/electricitydata.asp?COUNTRY_CODE=EG.

IEA. (2006b). *Natural Gas in Egypt for 2006*. Retrieved November 2009 from: http://www.iea.org/Textbase/stats/gasdata.asp?COUNTRY_CODE=EG

IEA. (2008a). *Energy Technology Perspectives 2008*. Paris: IEA.

IEA. (2008b). *Renewable Energy Essentials: Wind*. Retrieved November 2009 from: http://www.iea.org/Papers/2008/Wind_Brochure.pdf.

IEA and OECD. (2008). Prices and Taxes. Quarterly Statistics. Third Quarter 2008. Paris: OECD.

IMF. (2008). *World Economic Outlook 2008*. Washington DC: IMF.

Ministère de l'Ecologie, de l'Energie, du Developpement durable et de la Mer. (2008, November 28). *Mediterranean Solar Plan*. Paper prepared for the Mediterranean Solar Plan conference, November 22, 2008, Paris. Retrieved November 2009 from: http://www.developpement-durable.gouv.fr/article.php3?id_article=3928&var_recherche=mediterranean+solar+plan.

Ministry of Electricity and Energy (2007). Five year plan (2007-2012). Egypt: MOEE.

Morgan, T. (2008, September). *Subsidy Watch*. Global Subsudies Initiative. Winnipeg, MB: GSI and IISD.

National Democratic Party Energy Committee and SC. (2007, November). Energy and Development.

National Democratic Party Energy Committee and SC. (2008, November). Energy and Development.

National Renewble Energy Authority. (2007). Annual Report 2006–2007. Egypt: NREA.

New and Renewable Energy Authority (NREA). (2007). Annual Report, 2006–07. Egypt: NREA.

NREA. (2008). Annual report 2007–2008. Egypt: NREA.

Pearce, Fred. (2008, December 12) *Green "Super-Grid" Could help European Harvest African Sun*. Retrieved November 2009 from *New Scientist:* http://www.newscientist.com/blogs/shortsharpscience/2008/12/plans-for-a-super-grid-across.html.

Royal Academy of Engineering. (2004, March). The Cost of Generating Electricity: A commentary on a study carried out by PB Power for The Royal Academy of Engineering. Retrieved November 2009 from: http://www.raeng.org.uk/news/publications/list/reports/Cost_Generation_Commentary.pdf.

UK Department for International Development (DFID). (2008, Octber 3). Section 4.4: Technology Leapfrogging: A review of the evidence. A report for DFID by the Sussex Energy Group, SPRU.

UNEP. (n.d.) UNEP Risoe CMD/JI Pipeline Analysis and Database. Retrieved January 1, 2009 from: www.cdmpipeline.org.

WTO (n.d). *WTO Member Information – Egypt.* Retrieved March 27, 2009 from: http://www.wto.org/english/thewto_e/countries_e/egypt_e.htm.