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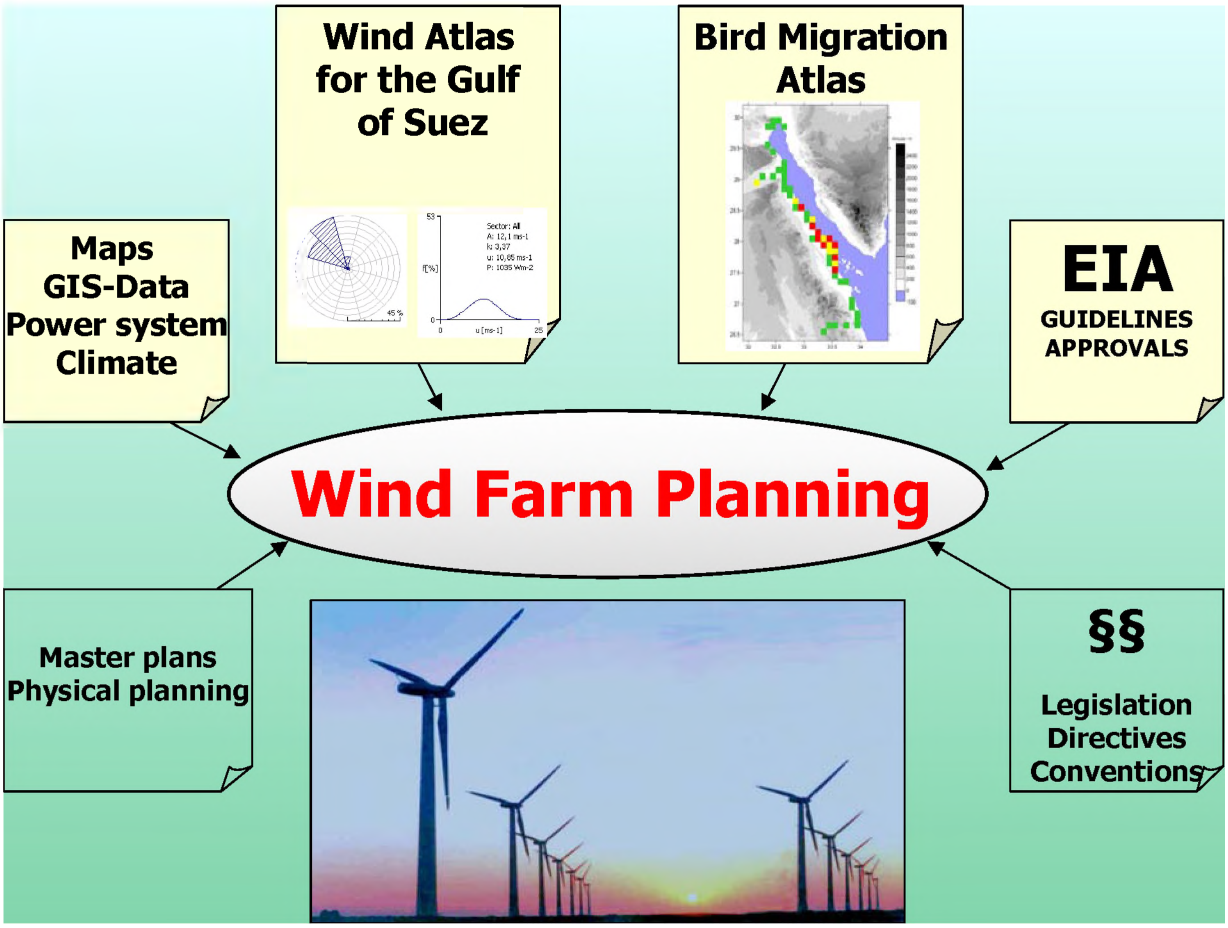
Wind Farm Planning at the Gulf of Suez

Niels-Erik Clausen[1] (ed), Niels G. Mortensen[1], Jens Carsten Hansen[1], Ib Clausager[2], Flemming Pagh Jensen[3], Laila Georgy[4], Usama Said Said[4]



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Risø National Laboratory
Roskilde
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Abstract (max. 2000 char.):

The Wind Atlas for Egypt project is an element in a national effort to provide the best possible basis for planning of future environmentally sustainable development and utilization of wind energy resources and technology in Egypt. The present report compiles the data, information and recommendations available for planning of wind farm projects in the Gulf of Suez.

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PREFACE

The present report Wind Farm Planning in the Gulf of Suez is a result of the Egyptian-Danish project *Wind Atlas for Egypt*. The Danish contribution to this project includes printing of the reports (25 copies to be shared) and is funded by the Danish Ministry of Foreign Affairs through Danida.

The other reports in this project are – see list of References:

1. Wind Atlas for the Gulf of Suez 1991-2001
2. Bird Migration Atlas for the Gulf of Suez
3. Review of bio-diversity and bird migration
4. Review re. EIA in Egypt
5. Preliminary Wind Atlas for Egypt
6. Meso-scale wind modeling for the Gulf of Suez with KAMM
7. Satellite imagery for the Gulf of Suez
8. Specific Guidelines for Environmental Impact Assessment of wind turbines and wind farms in Egypt - EEAA Specific Guidelines

Project Progress Report #2 for the period April 1998 to October 1998.
Project Progress Report #3 for the period October 1998 to May 1999.
Project Progress Report #4 for the period May to November, 1999.
Project Progress Report #5 for the period November 1999 to May 2000.
Project Progress Report #6 for the period May 2000 to October 2000.
Project Progress Report #7 for the period October 2000 to May 2001.
Project Progress Report #8 for the period May to November 2001.
Project Progress Report #9 for the period November 2001 to May 2002.
Project Progress Report #10 for the period May 2002 to February 2003.
Project Progress Report #11 for the period February 2003 to April 2004.

Glossary

BOO	Build – Own – Operate
BOOT	Build – Own – Operate – Transfer
CDM	Clean Development Mechanism
COE	Cost of energy
DGS	Diesel Generator Set
DMU	National Environmental Research Institute, Denmark
DRE	Decentralised Renewable Electrification
EDF	Electricité de France
EIA	Environmental Impact Assessment
EMS	Energy Management System
ESMAP	WB Energy Sector Management Assistance Programme
ETDE	Energy Technology Data Exchange
EWDS	European Wind Diesel Software Package
FLH	Full load hours
GEF	Global Environmental Facility
GUI	Graphical User Interface
IGBT	Isolated Gate Bi-polar Transistor
IEA	International Energy Agency
IEC	International Electro-technical Commission
IHRE	Integrated Hybrid Renewable Energy
IRES	Integrated Renewable Energy System
IRR	Internal Rate of Return
KAMM	Karlsruhe Atmospheric Meso-scale Model
LAC	Levelized annual costs
LHV	Lower Heating Value
LPC	Levelized production cost
LOLE	Loss of load expectancy
LOLF	Loss of load fraction
LOLP	Loss of load probability
LRMC	Long run marginal cost
NPV	Net present value
NREA	New and Renewable Energy Authority, Egypt
PAS	Publicly Available Specification
PCF	Prototype Carbon Fund
PV	Photovoltaic
O&M	Operation and Maintenance
QPW	Quattro Pro for Windows
PPA	Power Purchase Agreement
RAPS	Remote Area Power–supply System
RE	Renewable Energy
ROE	Return on Equity
SHS	Solar home system(s)
SQI	Service Quality Index
STMC	Short term marginal cost
UNDP	United Nations Development Program
VOE	Value of Energy
WAsP	Wind Atlas Analysis and Application Program
WB	World Bank
WD	Wind-diesel
WECS	Wind Energy Conversion System
WMO	World Meteorological Organization
WTG	Wind Turbine Generator

Executive Summary

The Wind Atlas for Egypt project is an element in an Egyptian effort to provide the best possible basis for planning of future environmentally sustainable development and utilization of wind energy resources and technology in Egypt. The present report aims at compiling data, information and recommendations available for planning of wind farm projects in the Gulf of Suez.

A comprehensive wind farm planning basis is in place for the Gulf of Suez, particularly for the western shore between Suez and Hurghada. This wind farm planning basis provides the regional data and information relevant for the planning process, including:

- Wind Atlas for the Gulf of Suez, including a database of wind data 1991-2001
- Bird Migration Atlas for the Gulf of Suez
- EIA Guidelines - EEAA
- Terms of Reference for scoped EIA
- Wind Farm Planning Report (the present report)

Sections 1, 2, and 3 provide a brief overview of the general background, an introduction to planning aspects, a status on internationally wind turbine technology, wind farm planning tools, and a chapter on birds and wind turbines.

Section 4 specifically addresses wind farm planning methodologies relevant for the Gulf of Suez region in Egypt, including a discussion of energy production estimation and uncertainties.

Section 5 applies the proposed methodologies and background atlases developed by the wind atlas project to a particular case in the Gulf of El Zayt – in the southern part of the Gulf of Suez. The Gulf of El Zayt has been selected as the case because of its extremely high wind energy resource and the fact that at the same time it is an international "highway" for bird migration.

The wind resource assessment in the Gulf of Suez is based on both high-quality observations *and* state-of-the-art models. Engineering wind resource assessments and energy production estimations are thus in general relatively reliable due to the existence of the long-term meteorological stations in the area operated 1991-2004 as part of the wind atlas projects in the Gulf of Suez. Furthermore, the terrain is quite simple, both with respect to elevation and land-use.

The largest uncertainties are therefore related to meso-scale effects and the long-term variation of the wind resource, in particular to what extent such changes may modify the flow patterns found in this area. It should be noted that the variation in wind resource is very large within the Gulf of Suez area, and that big differences in annual energy production of wind farms may be found for different sites. Calibration and verification of flow modeling parameters by on-site measurements is therefore recommended. In order to limit uncertainties, the recommended approach should be applied as indicated in Section 4, source by source.

In general, it is recommended to specify and design wind farm projects in accordance with the standards of the International Electrotechnical Commission (IEC) for wind power, including

- IEC61400-1 Wind turbine design and safety
- IEC61400-12 Wind turbine power performance testing
- IEC WT 01 (2001-04) IEC System for Conformity Testing and Certification of Wind Turbines - Rules and procedures

It should be noted that the hubheight annual average wind speeds, $V_{ave,}$ at certain sites in the Gulf of Suez exceed 10 m/s - the upper limit for standard wind turbine class 1 - which means that IEC Class S wind turbines should be applied, and special care should be taken to specify in detail the site-specific design conditions. Such wind turbines may not be standard products from the manufacturer, and a site-specific certification will be strongly recommendable.

Due to the non-standard high annual average wind speeds in the Gulf of Suez, optimization of wind turbine design may potentially improve cost-efficiency compared to applying standard wind turbines. It should be considered to design wind turbines for higher maximum tip-speed. Similarly the relatively low extreme winds may give savings in some load cases. Such suggestions may be specified to bidders for projects.

The wind resource assessment allows for extrapolation of wind resource estimates over most of the region. This, however, is not true for the bird migration studies. While a very important and necessary data material on bird migration has been established for the Gulf of Suez - “Atlas of Bird Migration in the Gulf of Suez area”, Ref. [2] - detailed and reliable models and procedures for extrapolating these observations more generally to any wind farm site in the region are not available. This means that predictions of bird migration patterns and densities to be made at a specific wind farm site will require field monitoring.

It is strongly recommended that the EEAA Guidelines (EEAA) for environmental evaluation of wind farm projects are followed, including if needed carrying out Environmental Impact Assessments in accordance with the recommendations using the “Atlas of Bird Migration in the Gulf of Suez area”, Ref. [2], and the Terms of Reference for a "scoped EIA". In most sites of the Gulf of Suez area a partial EIA is sufficient, and field monitoring, however, is only necessary in some “hot spots” marked on maps in Ref. [2], where a full EIA should be made. In initial phases of wind farm development in these “hot spots”, projects should be planned with monitoring programmes during migration seasons in order to avoid bird-wind turbine collisions – especially at El-Zayt.

Most of the potential impacts of wind farms on migrating birds can be reduced to acceptable levels through careful siting, design and mitigation. The most crucial aspect is the siting of the wind farm. Identifying areas of possible concern should therefore be done as early as possible in the planning stage, in order to minimise the cost, and maximise the effectiveness, of these measures. In high-risk areas the ultimate solution could be to stop all or some of the wind turbines for part of the days during migration. Decision and assessment of such possibilities will require more detailed studies.

1 Introduction

The present report is part of the Wind Atlas for Egypt project, which should be seen as an element in a national effort to provide the best possible basis for planning of future environmentally sustainable development and utilization of wind energy resources and technology in Egypt. The project should recommend a common planning framework for wind farm development in the Gulf of Suez, giving an overview of planning and feasibility studies necessary as well as of rules, regulations, data and information applicable in the Gulf of Suez. The framework should be particularly aimed at obtaining accurate wind energy production estimates, wind farm siting methods and appropriate environmental impact assessment, essential for future investment decisions and development. Environmental impact assessment should in general include main sources of air, water and soil pollution, various emissions and their distributions in space and time, noise, visual impact and impact on biodiversity. In the Gulf of Suez, with a known high density of migrating birds, the risk of collision between wind turbines and migrating birds will be assessed in the Atlas of Bird Migration for the Gulf of Suez and through a case study the planning tools are demonstrated at a site with a high potential for wind energy development, which at the same time is known to be close to a location with a high concentration of migrating birds – Gulf of El-Zayt.

Overview of existing guidelines for development of wind farms:

- AWEA Fact Sheets[1] - 10 steps in building a wind farm
- EWEA European Best Practice for Wind Energy Development (1999)
- BWEA Best Practice Guidelines for Wind Energy Development (1994)
- National Wind Coordinating Committee (NWCC) Siting Handbook
- AusWEA (2002)

Environmental assessment:

- IFC Guidelines
- Danish VVM Guidelines (in Danish)
- UNEP – CDM Guideline and Databook
- Specific Guidelines for Environmental Impact Assessment of wind turbines and wind farms in Egypt, including relevant associated technical installations - EEAA Specific Guidelines (see Section 3.3)

International standards to be considered

- IEC 61400 (parts 1 to 23)

It should be noted that the point of view presented in the present report is the opinion of the authors and not of the Egyptian Authorities.

1 http://www.awea.org/pubs/factsheets/10stwf_fs.PDF

2 Background

2.1 Wind power technology

Wind power is today a mature technology, which at windy sites is economic and competitive to conventional power generation technologies, in particular when taking into account the environmental impact. About 39,000 MW of wind turbine capacity is in operation worldwide (end 2003). Some 80% of this capacity was implemented in only 5 countries: Germany, Spain, USA, Denmark and India. The largest manufacturing capacity is based in Denmark, Germany and Spain. The technological development in the field of wind energy has been extraordinary since 1980, increasing the size of the largest commercially available wind turbines from 50 kW to about 4500 kW (with prototypes up to 6MW or larger planned). The development has dramatically reduced the cost per kWh produced from wind. In view of the market growth, the on-going up-scaling to larger sizes, and the new concepts already on the drawing board, it seems that cost-efficiency of wind turbines will continue to improve.

These perspectives and the globally growing environmental concern have lead governments to encourage and plan for wind energy development. In 1999 and 2002 Greenpeace and European Wind Energy Association (EWEA) published Blueprints for Wind Power Development – Wind Force 10 and Wind Force 12 – which suggested a target of 10% (and 12% respectively) of the world's electricity to be generated from wind by 2020. The target was set in order for wind power to make a significant impact on CO_2 emissions savings. The report demonstrates that a total of 1.3 million MW of wind power can be installed worldwide by 2020, producing more than the total electricity consumption in Europe

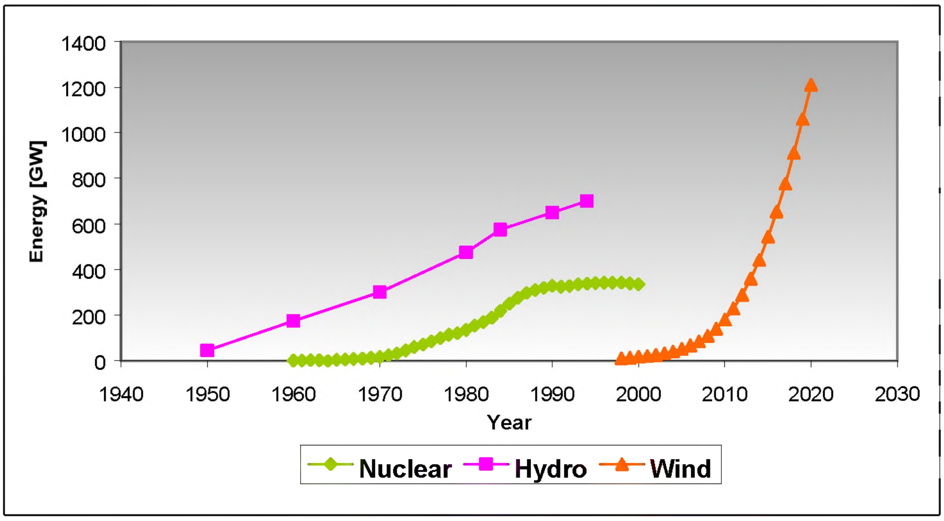


Figure 1 Greenpeace/EWEA/FED Blueprint for wind power to reach 10% of the global electricity supply by 2020 - compared to hydro and nuclear today

today. Figure 1 shows that today, although it is clean, wind power makes little impact on the environment due to the small capacity installed worldwide, but it also illustrates the tremendous challenge it is to develop new technologies to make a significant impact for a cleaner environment.

In order to reach 12% of the electricity consumption, much higher wind energy penetrations than 12% must be realized in the windiest regions of the world such as Denmark and not the least Egypt with its great resources and large new projects being developed. The technological background, some perspectives and recommendations are presented and discussed.

2.1.1 The typical wind turbine

Wind turbines transform kinetic energy in the wind to electricity. Almost all wind turbines are 'horizontal axis' machines with rotors using 2 or 3 airfoil blades. The rotor blades are fixed to a hub attached to a main shaft, which turns a generator – normally with transmission through a gearbox. Shaft, generator, gearbox, bearings, mechanical brakes and the associated equipment are located inside the nacelle on top of the tower. The nacelle also supports and transfers structural loads to the tower together with which it houses all automatic controls and electric power equipment.

The wind turbine automatically yaws the nacelle to the direction facing the wind for optimal energy production. The turbines are stopped at very high wind speeds to protect them from damage. Rotors may operate at constant or variable speed depending on the design. MW-size machines are all variable speed concepts. Typical rotor speeds at rated power range from 15 revolutions per minute and up – a factor, which influences the visual impact. The larger the rotor the lower the rotational speed in order to keep the blade tip speed in the optimal range – 60-80 m/s. Power output is automatically regulated as wind speed changes to limit loads and to optimise power production. The present "state of the art" of large wind turbines have:

- power control by active stall or pitch control (in both cases pitching blades) combined with some degree of variable speed rotor, and
- a two speed asynchronous generator, or a gearless transmission to a multi-pole synchronous generator and power electronics.

Wind turbines range in capacity (or size) from a few kilowatts to several Megawatts. The crucial parameter is the rotor diameter – the longer the blades, the larger the area swept by the rotor and thus the volume of air hitting the rotor plane. At the same time the higher towers of large wind turbines bring rotors higher above the ground where the energy density in the wind is higher. Totally, larger wind turbines have proven to be more cost-efficient due to improvements in designs and economics of scale, but also with a higher energy production per swept m^2, due to the higher towers and better aerodynamic design.

2.1.2 Wind turbine products on the market

At present the size of new machines being installed in wind farms on land or offshore is in the range 500-4500 kilowatts. Table 1 lists the biggest machine from each manufacturer of the top 7 suppliers worldwide.

Table 1. List of the two biggest (newest) wind turbines from each manufacturer of the top 7 suppliers worldwide. The name indicates nominal (maximum output) generator rating and rotor diameter.

Manufacturer (top 7 suppliers)	Wind turbines
Vestas (Denmark)	V90m – 3 MW
NEG Micon (Denmark)	NM 4.2 MW/110m
Enercon (Germany)	E-112 – 4.5 MW
Gamesa (Spain)	G-83m – 2.0 MW
GE Wind (USA)	3.6 MW/104 m
Bonus (Denmark)	2.3 MW/82.4m
Nordex (Germany)	N80m/2.5 MW

Other suppliers of both large and small wind turbines – some of which with quite different designs – exist from around the world, e.g. Ecotecnia (Spain), Repower (Germany), Lagerwey (Holland), Mitsubishi (Japan).

The focus and the big market potential today are within large wind turbines. It is a race among the leading suppliers to supply larger and more efficient machines sooner than the competitors for the large-scale and offshore applications.

2.1.3 Future design – trends and possibilities

The trend is towards even larger machines especially for offshore applications, whereas the present size range seems quite appropriate for on-land applications – the smaller sizes (500 – 2000 kW) especially where land availability is not a problem and in places with lack of large cranes and other equipment for the very large machines.

From research it is estimated that wind turbine blades in principle could be doubled in length using today's technology and materials. Wind turbine units could thus grow 4-5 times in terms of nominal kW capacity, but the development of application of wind turbines is not solely linked to the success of the up-scaling effort. There are many wind turbine designs already on the market, but there is still plenty of scope for innovation and technological development. The main R&D investment is today spent in up-scaling the best selling products, which all are 3-bladed, up-wind machines with stiff tower and rotor. In order to reduce weights especially of blades and transmission system, new design methods and better design tools are being developed. Further development of new more flexible design concepts reducing the wind turbine weight considerably is however possible and will most certainly be seen in the future of wind turbines for on-land applications. The resulting cost reduction may reach 25% within the coming 10 years if concepts with more flexible rotor structure, transmission and power conversion are developed. In to achieve this, the market situation must make it potentially attractive for the industry to pursue new concepts and investments must be made in research and development.

Know-how for wind turbine design available is to a very limited degree made available for design of specially adapted wind turbines for a particular application in a given region or country with its particular conditions.

The Gulf of Suez has very special wind conditions with very high annual average wind speeds, rather low ambient turbulence intensity as well as significantly lower extreme wind speeds than most other places on earth with high annual averages. Such wind conditions, including the fact that it is highly unidirectional from north to northwest, provides opportunities for optimization of cost efficiency by specially adapting wind turbine design and wind farm layouts.

2.1.4 Wind power applications

Applications of wind turbines may be categorised as indicated in Table 2, which is useful for the analysis and discussion of the technological barriers and opportunities. Table 2 also shows the unit size of wind turbines that is typically applied in the different categories.

Table 2. Categorisation of wind power systems.

Installed Power	Categorisation	wind turbine size
< 1kW	Micro systems	< 1kW
1 - 100kW	Wind home systems and hybrid systems	1-50kW
100kW - 10MW	Isolated power systems and decentralised generation	100kW-1MW
10 - 100 MW	Wind Power Plants – wind farms on-land	> 500kW
> 100MW	Wind Power Plants – wind farms offshore	> 2000kW

A lot of similarities exist between the categories, but some differences and challenges become obvious when looking into details of actual projects and experience.

The wind energy penetration level of some real power systems from the different categories in Table 2 are plotted in Figure 2 as a function of the total power system size. The situation in Denmark in 1998 and as planned for the year 2030 have been used as an indication of the large power systems. The dashed trend line shows the degree to which the level of wind energy penetration of actual power systems with successful track records decreases as the power system size increases. The dotted line indicates a possible future development towards higher penetration levels, which may be achieved in the coming 20-30 years. The benchmark points assumed for the dotted line are

- Frøya Island – a Norwegian research system aiming at maximum penetration
- Denmark in 2030 according to the plan of action for energy developed by the Danish authorities in the late 1990ies

The feasibility of very high wind energy penetration is seen to change dramatically in the 100kW-10MW system size range. In this range conventional electricity generation is still diesel based and cost of energy rather high, but not necessarily varying a lot through this range. The main reason for the dramatic drop in penetration is rather that energy storage is needed to reach the very high penetration levels and that large systems require a cautious approach.

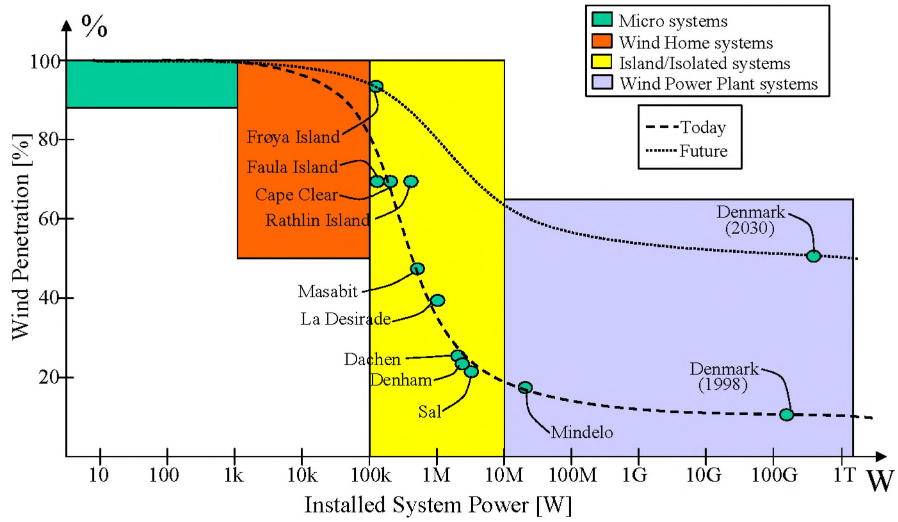


Figure 2. Present time and future development of the Wind energy penetration vs. the Installed system power

As indicated by the dotted line in Figure 2, the level of wind energy can be developed to increase significantly in the future. Thus the challenges of national (and Trans-national) systems will be to increase penetration to levels already existing in small isolated systems, which themselves seem to be well placed to increase their wind energy penetration to levels typical for just slightly smaller systems. Obviously great care has to be taken in this process, where many failures have occurred due to over-ambitious system designs with too high degree of complexity and too little experience as a background for the project development. Gradual increase starting at the dashed line and moving towards the dotted step-by-step applying simple, robust, reliable and well-tested concepts seems to be the recommendable approach.

2.2 Wind energy plans and development in Egypt

Egypt is a north African/Mediterranean/Middle East country extending between latitudes 22°-31.5° North and longitudes of 25°- 35° East with long coast areas on the Red Sea and the Mediterranean Sea. The total area is about one million km^2 with more than 94% desert. The 2000 population is about 69 million persons, increasing at approximately 2% rate of growth, with 55% living in the countryside around the Nile valley.

Securing energy resources on a continuous basis is a vital element for development, and can be considered of prime importance for Egypt to accomplish sustained national development plans. For more than forty years, Egypt has given due consideration to the development of its conventional energy resources, mainly oil and lately natural gas. But Egypt's primary energy requirements have significantly increased during the 1980's while the rate of increase reached about 6% in the last decade.

In view of Egypt's limited proven fossil fuel reserves, the government has realized since the early 1980's that conventional energy sources will fall short of satisfying the growing energy needs, thus, requiring other energy resources for establishing an optimum energy mix along with implementing energy conservation measures. Accordingly, a national strategy for the promotion and development of renewable energy applications and energy conservation measures was formulated in 1982 (later updated) as an integral part of the national energy planning.

The main targets of this strategy is to cover about 3% of the electric energy demand by the year 2010 from Renewable Energy Resources (excluding hydro power) such as, Wind, Solar, Biogas, etc., most of which will be from wind contributing 600 MW installed capacity by 2010. On the other hand, the worldwide growing concerns of avoiding pollution and negative impacts on the environment of burning fossil fuel, particularly the global warming issue, has accelerated efforts to promote renewable energy resources utilization in Egypt.

2.2.1 Power Sector in Egypt

The power sector of Egypt is operated by nine executing authorities, namely, Egyptian Electricity Holding Company (EEHC), Rural Electrification Authority (REA), Hydro Power Project Execution Authority (HPPEA), Atomic Energy Authority (AEA), Nuclear Power Plants Authority (NPPA), Nuclear Material Authority (NMA), Organisation for Energy Planning and policy analysis (OEP), Egyptian Electric Utility and Consumer Protection Regulatory Agency (EEUCPRA) and New and Renewable Energy Authority (NREA), all under the control of the Ministry of Electricity and Energy (MEE) as shown in Figure 3.

The Egyptian Electricity Holding Company (EEHC) is responsible for operation and maintenance of thermal and hydro power plants. Its responsibilities also include power transmission, transformation and distribution associated with those power plants.

On July 2000, Egyptian Electricity Authority was converted into a joint stack company named the Egyptian Electricity Holding Company (EEHC). Later on, EEHC has been restructured into 13 affiliated companies: a sole transmission company, five-generation companies, and seven distribution companies. These affiliated companies are the regulated segment of EEHC.

Executing authority under the control of the MEE is New and Renewable Energy Authority (NREA), responsible for research and development, construction, and operation and maintenance of new and renewable energy projects. New and renewable energy principally includes wind, solar, and biomass. Responsibilities of NREA also cover energy conservation activities. The organization and activities of NREA will be further discussed in the next section.

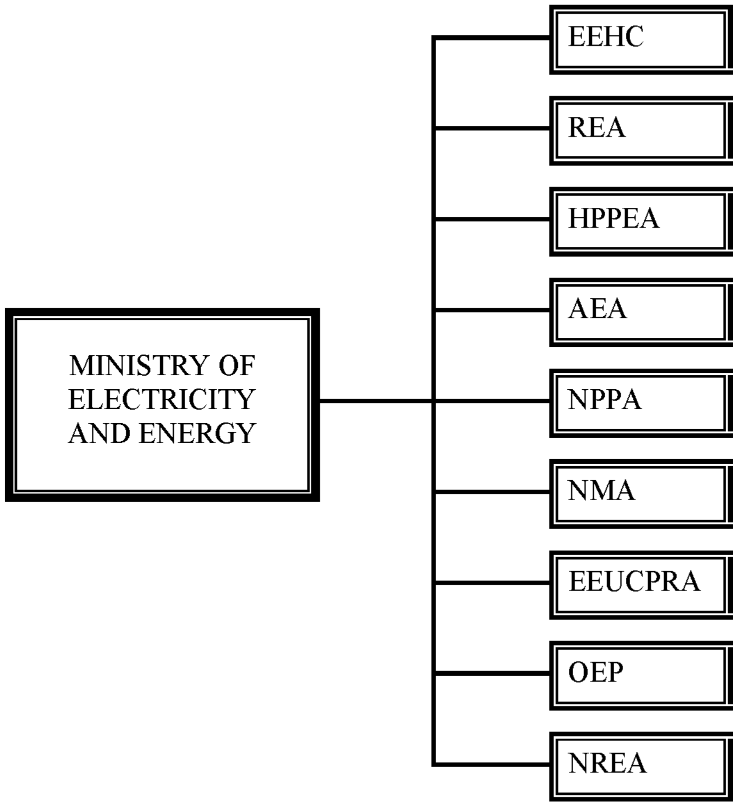


Figure 3. Schematic Organization of Egyptian Electricity Sector.

2.2.2 The Strategy and the Institutional Structure

Different Egyptian institutions have developed programs to achieve the renewable energy strategic goals of Egypt. They cover the whole spectrum of the activities required for renewable energy promotion, starting from policy and planning to the marketing and dissemination. As a result of these renewable energy strategic goals of Egypt growing interest, the New and Renewable Energy Authority "NREA" was established in 1986 to provide the institutional framework for the renewable energy strategy implementation and to act as a focal point for expanding efforts to develop and introduce renewable energy technologies in Egypt on a commercial scale. NREA is also entrusted to coordinate efforts with national, regional and international entities for:

- Renewable energy resources assessment.
- Development and introduction of new technologies.
- Renewable energy testing and certification.
- Pilot and field testing projects and evaluation.
- Market and economic evaluation studies.
- Technical and environmental feasibility studies.
- Support of the formulation of energy labeling programs.
- Support of technology transfer and local manufacture of renewable energy equipment.
- Training of engineers, technicians and users.
- Offering information services as well as developing and implementing information.

- Dissemination of information and public awareness programs.

In the course of implementing the renewable energy strategy, NREA has been updating it periodically to reflect projections for possible contribution of identified renewable energy technology/application options, to the strategic objectives.

Currently, the main options are:

1. Large-scale wind farms for electricity generation.
2. Small scale wind for pumping and electricity generation.
3. Solar thermal water heating for domestic and commercial sectors.
4. Solar thermal systems for industrial process heat.
5. Solar thermal electricity generation.
6. Photovoltaics for remote village and community electrification, for water pumping and other uses.
7. Biomass systems for rural and urban waste treatment.

One of NREA's unique achievements is the establishment of The Egyptian Renewable Energy Development Organization, "EREDO" as a specialized center which integrates a set of advanced laboratories for testing and certification of renewable energy components and systems.

EREDO includes indoor and outdoor laboratories for solar thermal low and high temperatures, photovoltaics, wind, biomass and energy conservation, as well as resource assessment and environmental measurement facilities.

Figure 4. NREA's Headquarters in Nasr City, Cairo.

2.2.3 NREA's Activities and Accomplishments within Wind Energy

Numerous activity accomplishments have been made by NREA in promoting R.E. utilization while others are underway for implementation. Some of the main activities and accomplishments will be presented below.

Encouraged by the huge wind potential available in Egypt (average annual wind speed reaches 10 m/s in the Gulf of Suez), Egypt has already crossed the phase of limited scale demonstration and field testing projects to the intensive implementation of grid connected large wind parks with local manufacture of some main components, e.g. blades, tubular and lattice towers as well as other mechanical parts.

The first experimental commercial wind farms of 5 MW capacity is running successfully at Hurghada (on the Red Sea coast), while 143 MW wind farms at Zafarana (on Gulf of Suez) had started operation by the beginning of 2004. Expansion plans exist to increase the installed capacity up to 600 MW by 2010, 300 MW out of which is to be undertaken by private sector (B.O.O.T. scheme).

The wind energy technology center at Hurghada is intended to establish a location with a scientific environment, which will serve as a hub for capacity building in development of technology related to utilisation of wind energy.

The center will be able to serve clients both from Egypt and from other countries in the region representing universities, other scientific institutions, manufacturers, governmental authorities and decision makers, investors, end users, and so on.

A) Wind Energy Resource Assessment

Wind energy utilization was promoted to occupy the top priority of New & Renewable Sources of Energy (NRSE) as it seems the most attractive renewable energy source to rely on for effective contribution in achieving the targeted goal. Wind energy in Egypt is not a subject of prediction and speculation, it is based on precise scientific analysis and evaluation of output from 45 synoptic measuring stations. These masts were erected all over Egypt and proved the availability of abundant wind energy of theoretical potential of about 20.000 MW at the Western Coast of the Suez Gulf. Moreover about 80.000 MW at Gelf Ridge South West of Egypt East Oweinat in addition to the Northern Coast of Egypt and South Sinai.

B) NREA's Demonstration Wind Farms

The Government of Egypt has turned its attention to the environmental problems. NREA under auspices of Ministry of Electricity & Energy has started the establishment of several pilot, demonstration and field testing projects, and ambitious plans for the future are prepared. The implementation of the plans has already been initiated, a fact which can be concluded from the following:

In 1988 the 1st demonstration wind park was established in Ras Ghareb on the Gulf of Suez constituted of 4 units, 100 kW each WINCON type, stall regulated which were fully imported from Denmark.

In 1992 the 2nd demonstration wind project was established in Hurghada on the Red Sea Coast and associated with a program for transfer of manufacturing technology which resulted in the local manufacture of 45% of the value of equipment comprising towers, blades and nacelles. Hurghada demonstration wind park is constituted of 4 units, 100 kW, partly locally manufactured wind mills.

The above mentioned demonstration wind parks were interconnected to the local electrical distribution grids with fully successful operation.

C) First Semi-Commercial Wind Park In Hurghada

NREA has implemented wind energy projects at the NREA Site in Hurghada. The wind park consists of 38 wind turbines with a total installed capacity of 5 MW including different designs and different sizes in successive phases:

The first phase of 1 MW capacity was operated in June 1993 using 10 units, 2 blades & 100 kW each, pitch regulated machines, Ventis type.

The second phase of 2 MW capacity, consists of 20 units, 3 blades & 100 kW each, stall regulated machines, WINCON type the park has started operation in June 1994.

The third phase of 1.8 MW capacity constituted of 6 units, 3 blades & 300 kW each, stall regulated machines Nordtank type; the park has been running successfully since 1995

Rehabilitation and installation of 2 wind turbines that were previously erected in Ras Ghareb.

D) Commercial Large Scale Wind Farms

The assessment of the wind energy resources along the Red Sea Coast has showed a very high potential. The coast of the Suez Gulf is characterized as one of the best areas worldwide, having a theoretical wind energy potential exceeding 20000 MW. Moreover feasibility studies proved the economical feasibility and technical viability of establishment large-scale wind parks at the Gulf of Suez. Based on that, Egypt has crossed the stage of limited capacity demonstration and field testing projects to the stage of implementing large grid connected wind park projects, owned by the Government or by the private Sector. An area of 80 km^2 was dedicated for NREA by a presidential decree for these projects along the Suez Gulf as an institutional support and Governmental Commitment to the wind energy program. The program is to construct a 600 MW wind park in successive stages. Each stage has about 60 MW capacity. NREA planned that 300 MW shall be jointly financed through the state budget and donor countries, while the private sector (local and foreign investors) are encouraged to finance the other 300 MW under the formula BOOT or BOO system. A 220/22 kV substation equipped with two 75 MVA transformers at Zafarana is already established together with a 220 kV transmission line for connection to the nearest substation in the national grid. Furthermore, it is planned to replace the current transformers with two 125 MVA transformers.

2.2.4 Government Projects

Government projects can be classified into the following four stages:

The first stage:
The first stage of the program was the establishment of the first 60 MW wind park at the NREA site in Zafarana in cooperation with the Danish Government represented by DANIDA. The project will be implemented in two phases:

1^{st} phase 33 MW wind farm, operation started in March 2001.
2^{nd} phase 30 MW wind farm, completed December 2003.

The second stage:
The second stage of the program was the establishment of about 80-85 MW wind park in cooperation with the German Government represented by KfW. The project will be implemented in 3 phases:

1st phase 33 MW wind farm, operations started in March 2001.
2nd phase 47 MW wind farm, completed December 2003.

The third stage:
The third stage is the Egyptian/Japanese cooperation for establishment of 120 MW wind park. A feasibility study was prepared in March 2003.

The fourth stage:
The fourth stage is the Egyptian/Spanish cooperation for the establishment of 70 MW wind park. The tender document was issued in March 2003.

The fifth stage:
The fifth stage is the Egyptian/Danish cooperation for establishment of 120 MW wind park. A pre-feasibility study was prepared in 2003/4.

2.2.5 Private Sector Projects

According to the cabinet ministers' decision, the Egyptian Ministry of Electricity and Energy is preparing for the consultant selection for a 300 MW wind park in equal segments to be connected to the national network and selling the produced electricity to the Egyptian Electricity Holding Company according to a "Power Purchase Agreement - PPA". Wind energy projects for generating electricity are expected to continue either in the form of governmental or private sector projects to achieve the long term objective for the installed capacities to reach 1800 MW by the year 2017 located in Gulf of Suez, Red Sea Coast and Oweinat, rendering a favorable potential for establishing joint venture companies to locally manufacture wind energy equipment.

2.2.6 Plans for the Future

Until year 2017, the total expected power to be installed from wind energy technology in Gulf of Suez, Red Sea and Oweinat regions can reach 1800 MW. The total future installed power can be divided as follows: 600 MW in Gulf of Suez, 1050 MW in Red Sea Coast, and 300 MW in Oweinat region. Already the wind farms in the Gulf of Suez take shape, and the 450 MW may be exceeded within the coming 5 years.

2.2.7 Climate Change Projects

Under the Kyoto Protocol the European Community committed itself to reduce its emissions of greenhouse gases by 8% during the period 2008-2012 in comparison with their levels in 1990. In practice, this will require an estimated reduction of 14% compared to "business as usual" forecasts. Emissions trading, both internally within the Community and externally with other industrialized countries will help to reduce the cost to the Community of respecting its commitments. Together with other polices and measures e.g. CDM (Clean Development Mechanism) projects, emissions trading will be an integral and major part of the Community's implementation strategy. It is obviously an opportunity for Egypt that the EU countries will need to use all the tools at its disposal to fulfill its international commitments to reduce CO2 emissions.

Emissions trading, whether domestic or international, is a scheme whereby entities such as companies are allocated allowances for their emissions. Companies that reduce their emissions by more than their allocated allowance can sell their “surplus" to others who are not able to reach their target so easily.

A community emissions trading scheme would lead to one single price for allowances traded by companies within the scheme, while different unconnected national schemes would result in different prices within each national scheme. The development of the internal market has been one of the driving forces behind the EU's recent development, and this should be taken into consideration when creating new markets.

Several projects have studied eligibility criteria with a view to determine types of renewable energy projects eligible for CDM, methodology for evaluation of global environmental benefits, and possible financing scheme. Recently two projects have analysed the CDM potential using a wind farm in the Gulf of Suez as the case study.

2.3 Legislation and Guidelines related to planning for wind energy in Egypt

Specific guidelines for environmental evaluation of proposed wind farm projects, Ref [9], is available from 2004 with the Central EIA Department of the EEAA and the Environmental Management Units.
The Contents include:

- Introduction to the Egyptian EIA system
- Presentation of the Environmental screening system (Form B)
- Screening guidance to the EEAA and others regarding the potential environmental effects of wind farms and associated transmission lines
- Terms of Reference for a "scoped EIA" – if needed
- Guidelines on the overall structure and content of a scoped EIA report
- Environmental Screening Form B specifically developed for Wind Farms and associated Transmission Lines

Without going into any details, which is outside the scope of this report, the following relevant legislation may be mentioned:

- The Planning Act
- The Protection of Nature Act
- The Renewable Energy Act
- The Building Act
- The Environmental Protection Act
- The Agriculture Act

3 Regional planning for wind energy in the Gulf of Suez

3.1 From a Danish perspective

Following the energy crisis in 1973/74 the Danish Parliament realised that a more general and superior energy policy was needed. As a result of this the government presented the first energy plan in 1976. It has been succeeded by revised plans, which more and more focused on utilisation of sustainable energy sources instead of fossil fuels i.e. oil and coal.

In the most recent edition of the Danish Energy Plan from 1996 entitled "Energi 21" wind energy is the primary source of sustainable energy. The aim is to reach a total of 5,500 MW by 2030 deriving from wind turbines of which 4,000 MW is expected to be offshore. At the end of 2003 the capacity of installed wind turbines in Denmark constitutes 3,110 MW of which 233 MW is installed offshore.

3.2 Basic principles of planning

3.2.1 Purpose of Planning

Denmark is with an area of 43,500 km² and 5.3 million inhabitants densely populated. In order to secure a reasonable and visionary development of the land legislation concerning the physical planning has been in force and improved for many years.

The most recent planning act is from 1998. The aim of the act is to unify the social interests of land use and the protection of nature and environment in a way that the development takes place on a sustainable basis in respect of living conditions of humans and conservation flora and fauna.

The planning act is divided into chapters covering:
- overall planning of the country,
- region planning in the country,
- local planning in the municipal.

The planning act is including guidelines for the content of planning activities regarding other legislation, inspection, complaint and suit.

All larger constructions (including wind turbines) and changes in the open land, which are supposed to impact the environment, must not be initiated before a description including an EIA (Environmental Impact Assessment) analysis is prepared.

3.2.2 Legislation and institutional setup/functions in Denmark

On land the local municipal is the primary authority concerning development of the countryside. According to the planning act all physical development has to be applied for at the municipal.

At sea the State is the primary and responsible authority and applications concerning physical development has to be addressed to the State. As regards erection of wind turbines the applications are forwarded to the Energy Authority.

The following describes briefly procedures in relation to the physically development on land.

Applications are evaluated by the municipal and may be submitted to different authorities, non-governmental bodies and societies for comments. If there are too serious objections the application may be rejected or proposed changed into a direction that it complies with the objections.

When an application is accepted the municipal draw up a "local plan proposal" which must not be in opposition to the general municipal and regional planning. The "proposal" describes the project including evaluation of possible impact on nature and environment (EIA analysis). After approval of the "proposal" by the local and county council it is submitted to the public for a period of at least 8 weeks. All are allowed to raise objections to the proposal. After expiry of the period the local and county councils can after a political decision finally adopt the proposal. Some objections may result in changes of the proposal so it in a better way fulfils the conditions.

In the permission conditions for the development is set up which may include environmental impact assessment studies and monitoring. In relation to wind turbines it may comprise studies before, during and after installation of a wind farm.

3.2.3 Environmental Impact Assessment

Wind turbines produce energy without contribution to air pollution leading in general to a reduction in the emission of carbon dioxide, nitrogen oxides and sulphur dioxide. The use of wind energy may therefore contribute to reduce global climate change, as well as local and regional effects as acid rain and deterioration of air quality and associated health problems.

Although the environmental impact of wind energy obviously is lower than that of conventional energy sources, there are some potentially negative effects on the environment, especially when it comes to establishing wind energy schemes consisting of several hundred turbines.

Over the years the main environmental concern when constructing wind turbine parks has been birds colliding with wind turbines and associated power lines. This issue raises special concern in the Gulf of Suez area because of its geographical position along one of the main migratory routes for birds that breed in Europe, Russia and the Middle East and winter in tropical Africa.

The development of a wind farm usually requires the formulation of an Environmental Impact Assessment (EIA). In Egypt this is stated in Law No. 4 of 1994 concerning protecting of the environment. Among other things, the law demands Environmental Impact Assessments to be carried out if a proposed project is believed to have a negative impact on the environment.

Over the years the main environmental concern when constructing wind turbine parks has been birds colliding with wind turbines and associated power lines. This issue raises special concern in the Gulf of Suez area because of its geographical position along one of the main migratory routes for birds that breed in Europe, Russia and the Middle East and winter in tropical Africa.

One of the things that have to be decided in the initial planning process is how detailed this EIA should be. Information on when and how environmental impact assessment should be carried out in Egypt is given in "Guidelines for Egyptian Environmental Impact Assessment" published by EEAA. These guidelines specifically mention a list of projects that should be categorised as white, grey or black, defined as follows:

<u>White projects</u>: Projects that are believed to have little or no negative impact on the environment and where EIAs are not required.

<u>Grey projects</u>: Project that may result in substantial environmental impact and it therefore has to be determined if a partial EIA should be carried out.

<u>Black projects</u>: Projects, which are likely to have a significant negative impact on the environment, and therefore requires a complete EIA

In the guidelines wind turbines are listed as Grey projects that is requiring a partial environmental impact assessment. This is in line with both the World Banks Operational Directive and the European Unions (EU) Guidelines in which this type of development projects are rated Category B Projects which call for a partial EIA. A partial EIA is essentially a selective impact assessment that is confined to a review of certain specified kinds of impacts.

It is worth pointing out that that the Egyptian, World Bank and European Union EIA rating systems are <u>guidelines</u>. Partial Environmental Impact Assessment of a proposed wind parks may be perfectly sufficient in most cases, but in some cases it is not enough. A full Environmental Impact Assessments is required if a project – such as a wind park – is likely to have a significant adverse environmental and social impact that are sensitive, diverse and unprecedented. In some parts of the Gulf of Suez area this is likely to be the case because a wind farm here may be planned to be build in the middle of the bird migration corridor where millions of birds pass twice a years. If wind parks are planned in or close to such areas they may indeed possess significant adverse environmental impact and a full EIA should be carried out to assess this.

To determine in which part of the Gulf of Suez area a selective impact assessment is sufficient and a full EIA must be carried out it is necessary to analyse the distribution of migration corridors. This has been done and the results published in the Bird Migration Atlas of the Gulf of Suez, Ref. [2]. This report gives detailed information on in which sections of the Gulf of Suez low, medium and high risk for bird/wind turbine conflicts can be anticipated. This assessment is based on a very extensive field survey of the bird migration.

3.2.4 Legislation, directives and conventions – internationally and in Egypt

Non-exhaustive list of relevant legislation to the electricity sector in Egypt:

- Environmental Protection Law 4/1994
- Executive Regulation 338/1995
- Guidelines for Egyptian Environmental Impact Assessment (EEAA 1996)

Relevant International and regional directives and conventions:

- the Convention on Biological Diversity
- United Nations Framework on Climate Change
- the Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention)
- the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA)
- the Ramsar Convention on protection of wetlands of international importance.
- the Bern convention

3.2.5 Planning Process Methods for National and Regional levels

In view of national and regional development plans and respecting legislation, directives and conventions, the wind farm planning may be undertaken in collaboration with the relevant authorities based on available data and information – in particular presented in general documents, atlases and databases. Such atlases and databases of primary importance for wind farm planning are

- National policy and regional physical planning
- Power system
- GIS and map data
- Wind Atlas for the Gulf of Suez (incl. Database)
- Bird Migration Atlas of the Gulf of Suez
- Specific Guidelines for Environmental Impact Assessment of wind turbines and wind farms in Egypt - EEAA Specific Guidelines
- Environmental Assessments
- History of bird impacts and conditions

3.2.6 Software Tools and Methods for Wind Farm Planning and Design

WAsP

WAsP is the industry standard in wind resource assessment. The version used in this report is WAsP 8.1 (version 8.01.0019).

WAsP has been employed for more than 15 years within wind power meteorology and in the wind power industry – and has become the industry-standard PC-software for wind resource assessment. WAsP runs on Windows 98, Me, NT4, 2000 and XP, see the hardware and software requirements on http://www.wasp.dk/Download/WAsP/SystemRequirements.html.

WasP is sold as a single-user licence. Currently, more than 1350 users in over 90 countries have used WAsP for:

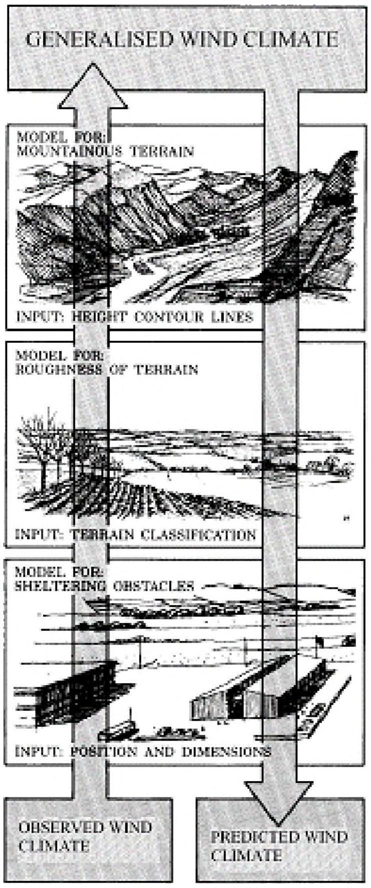
- Wind farm production

- Wind farm efficiency
- Micro-siting of wind turbines
- Power production of WTG's
- Wind resource mapping
- Wind climate estimation
- Wind atlas generation
- Wind data analysis
- Map digitisation & editing
- Power and thrust curve editing

WAsP at a glance:
- WAsP general specifications – System requirements, Installation guide, limitations, licensing,
- Working with WAsP – introduction to workspace, projects, set-up, options
- The WAsP models – flow model, roughness change model, model for sheltering obstacles, model for turbine wakes in wind farms
- Reports and scripts – standard and custom reports, batch mode
- Input required by WAsP – meteorological data, digital maps
- Output generated by WasP – reports, data files

The wind atlas methodology

The so-called wind atlas methodology is basically for the vertical and horizontal extrapolation of wind climate statistics enabling prediction of the wind climate statistics in a location different from the location of the measurement station providing the input wind data.



It contains several physical models to describe the wind flow over different terrains and close to sheltering obstacles. WAsP is a PC-program with an implementation of the wind atlas methodology, which may be summarised as follows:

Analysis

- time-series of wind speed and direction —> observed wind climate (OWC)
- observed wind climate + site description —> regional wind climate (wind atlas data sets)

Application

- regional wind climate + site description —> predicted wind climate (PWC)
- predicted wind climate + power curve —> annual energy production (AEP) of wind turbine

Wind farm production

- predicted wind climates + WTG characteristics + wind farm layout —> wind farm wake losses
- annual energy productions + wake losses —> net annual energy production of entire wind farm

For more details about the wind atlas methodology please visit: http://www.wasp.dk/Products/WAsP/WindAtlasMethodology.html.

The *Wind Atlas for the Gulf of Suez*, Ref [1], and the *Preliminary Wind Atlas for Egypt,* Ref [5], have both been developed using the wind atlas methodology and the WAsP PC-software package. The plan is that the Wind Atlas for Egypt will be completed in 2005 using the wind atlas methodology and the WAsP software as well.

WasP Engineering

WAsP Engineering is a PC program for the estimation of extreme wind speeds, wind shears, wind profiles and turbulence in complex terrain. Version 1.0 was launched in July 2001 at the European Wind Energy Conference and Exhibition in Copenhagen. Present version is 1.2 (2002).

The purpose of WAsP Engineering is to support the estimation of loads on wind turbines and other civil engineering structures situated in complex terrain. The wind properties that are treated are:

- Extreme wind speeds, e.g. the 50-year wind. If a wind turbine is well situated on a hill the mean wind speed and thereby the power production can be increased significantly compared to that over flat terrain. Unfortunately, the 50-year wind will increase correspondingly, maybe calling for increased strength of the blades or other parts of the turbine.

- Wind shears and wind profiles. Strong mean wind shears (large differences in the mean wind speed over the rotor) give large fluctuating loads and consequently fatigue on the wind turbine blades, because the blades move through areas of varying wind speed.

- Turbulence. Turbulence (gusts of all sizes and shapes) causes dynamic loads on various civil engineering structures, including wind turbines.

> The strength of the turbulence varies from place to place. Over land the turbulence is more intense than over the sea. Also the hills affect the structure of turbulence. We model various terrain dependent properties of turbulence.

A report on the WAsP Engineering - Ref [34] - may be downloaded from www.wasp.dk. The Ref [34] contains a complete description of the turbulence modelling in moderately complex terrain, implemented in WAsP Engineering. Also experimental validation of the model together with comparison with spectra from engineering codes is done.
Please also visit the WAsP Engineering home page - www.waspengineering.dk - for more information.

WindPro

The WindPRO Software Package is a spatial planning tool for planning of wind farms, developed and commercially available from Energi- og miljødata (www.emd.dk) as further briefly described below by Morten Lybech Thøgersen:

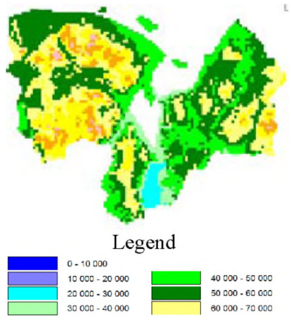
WindPRO is a software tool for project design and planning of wind farms or individual wind turbine projects. The software contains modules for energy calculation and optimisation (utilizing WAsP & CFD), visualization (photomontage & virtual reality), environmental analysis (noise, shadow flickering, zones of visual influence). Also included within the WindPRO package is a specialized planning module – WindPLAN. The aims of this module are computer aided planning of wind farms (spatial planning) as well a functioning as a support tool for the creation of an environmental impact analysis (EIA). This section briefly describes the capabilities of the spatial planning models included within the WindPLAN module. For further information, please consult the Ref [35] and Ref [36].

<u>Overview of the WindPLAN tools</u>
The WindPRO module named WindPLAN includes three interrelated spatial planning models (1-3) as three general support tools for the EIA-analysis (4-5). Only the spatial planning models (1-3) are briefly described below including output samples from the analysis in Nibe Municipality in Denmark.

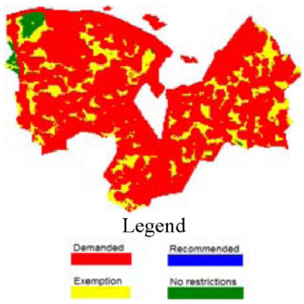
1) Weighted visibility calculation model
2) Conflict check calculation
3) Wind resource weighted planning
4) Calculation of emission savings and conventional resource savings (using baseline scenarios)
5) Drawing of terrain profiles with artificial objects
6) Generating of print ready and user customized maps

Data for the WindPLAN analysis is often re-used from the traditional wind turbine calculations. These data could be supplemented with imported detailed GIS-data, e.g. from AutoCad files (dxf) or from ESRI shape files (shp). Detailed result reports are available within the WindPRO system. It is also possible to export the spatial results to GIS systems.

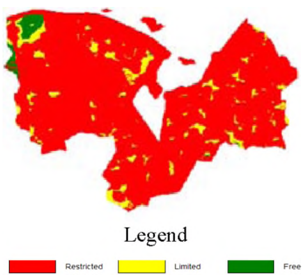
The Weighted Visibility Model:
The purpose of a weighted visibility analysis is to identify areas within a region, where turbines may be erected with the smallest possible visual impact. Thus, the weighted visibility analysis can identify areas where the erected turbines are not visible to the majority of the inhabitants, such as due to forests or hills hiding the turbines. A weighted visibility analysis has some relationship to the zones of visual influence analysis (ZVI). The ZVI generates a map of the visibility impacts of specific turbines with fixed positions, whereas the weighted visibility analysis calculates a map in a grid, where it is calculated for each grid point how visible a WTG positioned at this grid point would be. The visibility is defined as the accumulated visible impact area of the turbine considered.



The Conflict Check Calculation:
The conflict check analysis processes information of required distance demands from the geographic objects to the turbines (e.g. ancient monuments, preservation areas). These distance demands are found in various laws and possibly also in local requirements. The distance demands are often functions of the turbine properties (such as total height or rotor diameter), the subject heights (such as the height of a forest) or the subject areas (such as the area of a lake). Furthermore, the requirement may be conditioned on certain properties, i.e. the requirement is valid if only a forest is larger than a certain size. The distance demands are evaluated in three different groups: demanded, exempted and recommended. Areas not evaluated as belonging to one of the three groups are marked as having no restrictions.



The Wind Resource Weighted Planning:
The idea behind wind resource weighted planning is to weight the protection interest versus the available wind resource. Initially, the user must specify the protection interests and wind resource within a certain area. Then new polygons/areas with unique wind classifications and specific protection values are generated through a polygon dividing and merging algorithm. The input data may be generated through a conflict check calculation, a weighted visibility calculation and a wind resource map calculation. The wind resource weighted planning procedure, requires also the specification of a decision table. This table specifies how a polygon with a certain annual mean wind speed and certain protection value should be classified.



3.3 Background conditions and data

In this section we identify and summarize those conditions and data that exist for the Gulf of Suez and which are particularly important for the physical planning related to the establishment of wind farms in this area.

3.3.1 Topography and land-use

Physical planning – whether of wind farms, wind farm related installations, or any other human activity in the landscape – requires basic information on the topography and present land-use. Such information is recorded graphically in topographic maps.

The reference, large-scale topographical atlas to be used in the Gulf of Suez is the *Egyptian Series 1:50,000*, published since 1989 by the Egyptian General Survey Authority. This map series was compiled from aerial photography in the late 1980ies and further verified and completed in the field before publication. Each map sheet covers an area of 15′ longitude by 15′ latitude (approx. 25×28 km^2) and is drawn in a Transverse Mercator projection. The maps contain information on the elevations of the terrain surface, as well as the land-use and other natural or man-made features found in the terrain, see Figure 5.

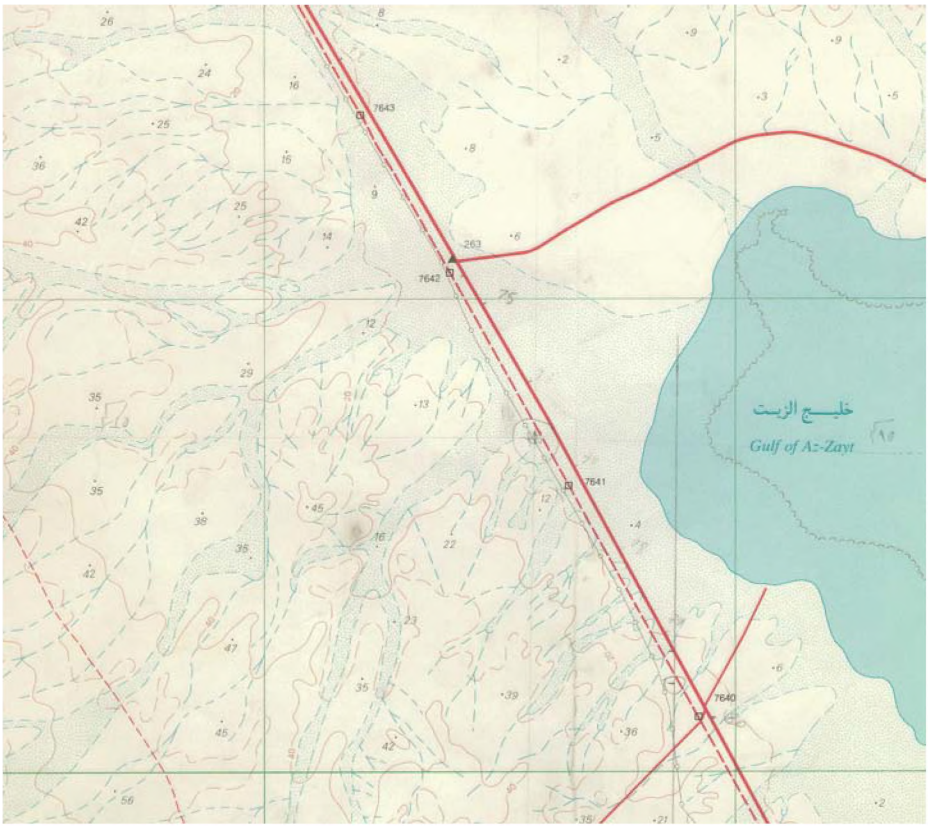


Figure 5: Example of a map sheet from the Egyptian Series 1:50,000.

The *elevation* of the terrain surface is described by height contour lines with a vertical contour line interval of 20 meters. In flat or lowland areas (coastal plain), additional contours with an interval of 10 meters are provided. In addition, terrain spot heights, depressions and escarpments are also indicated.

The *land-use* of the terrain is described in a few broad categories: water bodies, bare ground and vegetated surfaces. These broad categories are subdivided as follows:

Water bodies	• Sea, perennial lake, intermittent lake or pond, Sabkhah, marsh • River or stream, wide wadi, narrow wadi, dissipating stream, canal, drain, well, spring
Bare ground	• Sand, sand dunes, rocks, coral reef • Built-up areas, see below
Vegetated surface	• Cultivated area, orchards and trees • Palm trees, bush, grass

Overall, bare ground and water bodies (the Gulf of Suez and Red Sea) are by far the most important types of land-use in the Gulf of Suez area; vegetated surfaces will only play a role in a few places close to towns or settlements.

It should be borne in mind, that a map is a snapshot of the topography, representing the conditions at the time of publication. Whereas the surface elevations are usually not subject to drastic changes over, say, 10 years, the land-use in parts of the Gulf of Suez, i.e. coastal areas or close to towns, may change rapidly. Consequently, the land-use information derived from the topographical map should be verified and updated, e.g. during a site visit to the area in question.

3.3.2 Wind resources

A number of factors have to be taken into account when a site or an area is being assessed for its usefulness in relation to wind energy deployment. From a wind power meteorological point of view, Ref.[11], identified the following factors as being particularly important:

- mean wind speed (@ hub height)
- extreme wind speed (mean/gust)
- turbulence intensity
- wind farm (wake) turbulence
- non-horizontal flow (mean/gust)
- temperature (min-/maximum, yearly/daily variations)
- rain/ice/snow/hail
- atmospheric stability
- spectra and coherences
- humidity
- salt/dust/insects/algae
- chemical effects
- lightning
- earthquakes
- electrical grid

While most of these factors will have to be evaluated and dealt with in each concrete wind farm project, it is neither possible nor feasible to include all these parameters in the planning process. However, information on the overall distribution and magnitude of the wind resources in the Gulf of Suez must be available for the planning process. Such information is available in the *Wind Atlas for the Gulf of Suez,* Ref. [1].

The *Wind Atlas for the Gulf of Suez 1991-01* presents the results of a comprehensive 10-year wind resource assessment program in the Gulf of Suez and northern Red Sea. The aim of the program has been to establish the climatological basis for the assessment of the wind energy resources along the Gulf of Suez and the northern Red Sea, in particular in areas which – from a wind power meteorological point of view – seem interesting for wind power deployment. The main objective has been to provide reliable and accurate wind atlas data sets for evaluating the potential wind power output from large electricity producing wind-turbine installations. In addition, the wind atlas provides data and some guidelines for the meteorological aspects of the detailed siting of large and small wind turbines.

The Wind Atlas for the Gulf of Suez employs wind speed and direction measurements taken from 1991 to 2001 at 13 meteorological stations along a 250-km stretch of the Gulf of Suez and the northern Red Sea. In addition, historical data from two stations in the Gulf have been analyzed, see Figure 6.

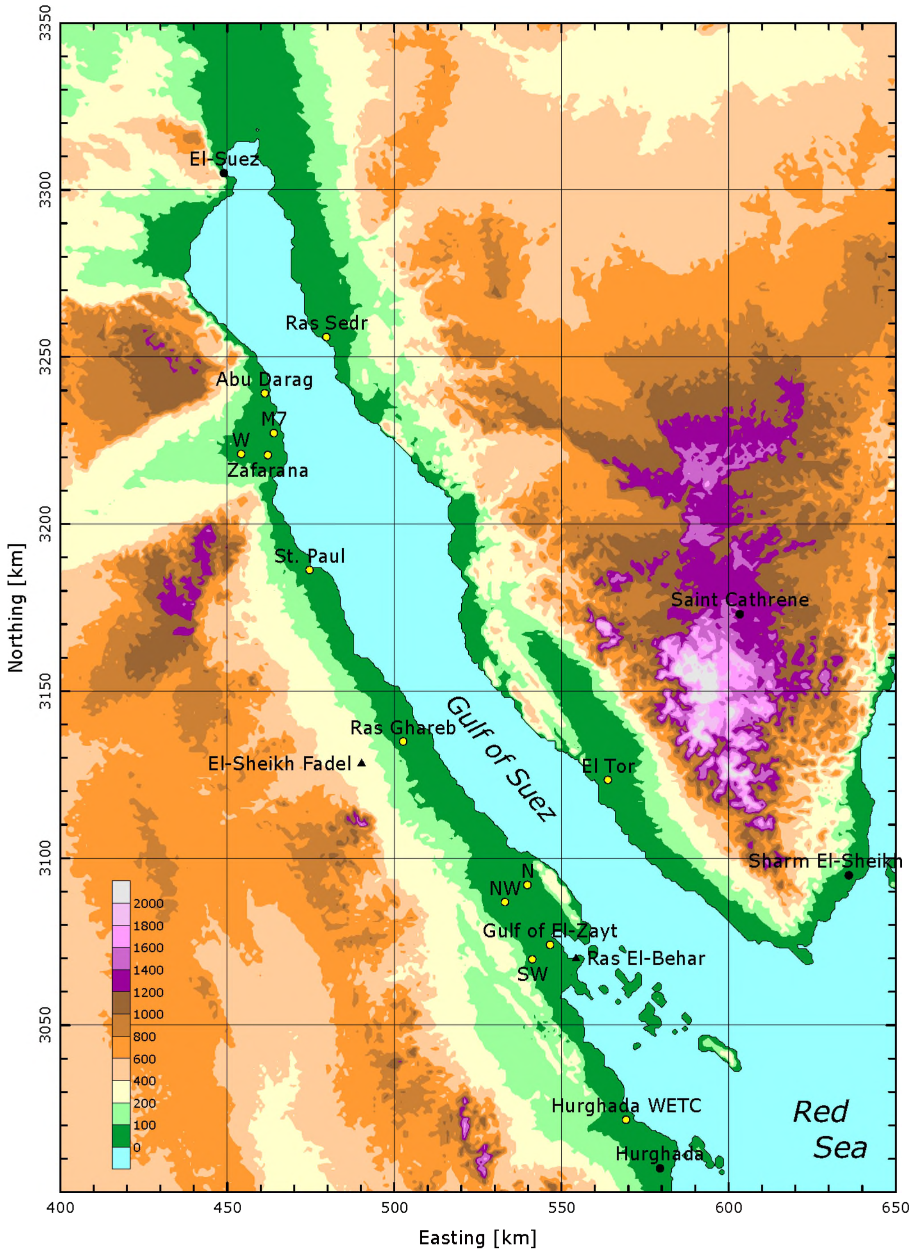


Figure 6: Elevation map of the Gulf of Suez, Egypt; elevations are given in meters above mean sea level. Meteorological stations are marked with yellow symbols. Cartesian UTM coordinates are referenced to World Geodetic System 1984 (WGS 84). Historical stations are shown with triangles.

Twelve 25-m masts were erected specifically for the wind resource study, but they also provide information on other climate statistics as well: atmospheric pressure, air temperature, air temperature gradient, atmospheric stability, wind speed profiles, extreme wind speeds, and gustiness of the wind. Satellite imagery obtained from NOAA 11 AVHRR data are used to map land and sea surface temperatures. The wind data from the 13 stations have been analyzed using the Wind Atlas Analysis and Application Program (WAsP), following the procedures and guidelines of the European Wind Atlas, Ref [13]. This analysis has lead to a regional wind climate for each site, which can be used for estimating the wind resource in an area around the site – where this area has a radius on the order of 10 km.

In addition to the measurements and WAsP modeling, the wind atlas also contains the results of meso-scale modeling of the entire Gulf of Suez, see Figure 7. These results may be used to extra- and interpolate the regional wind climates described above – albeit with a lower accuracy.

3.3.3 Other considerations

In addition to the elevation and land-use of the terrain, the topographical map contains a number of other features, which will or may have an impact on the planning of wind farms in the Gulf of Suez. These features are:

Roads	• Dual carriage, main paved, secondary, unpaved, track, path • Tunnel, bridge, culvert
Railways	• Single, double track • Stop, station, bridge
Buildings	• Government buildings, ruins, wall, wire fence, mosque, church, cemetery, historical monument • Quarry, oil well, oil tank, water tank
Line and point features	• Electric power lines, telephone lines • Oil/gas pipeline, water pipeline • Radio transmission antennas
Boundaries	• International, governorate, markaz, village

Some of these features are stable for many years while others may change rapidly. The information derived from the topographical map should therefore be verified and updated, e.g. during a site visit to the area or by contacting the authorities responsible for the physical planning in the area.

Finally, some very important terrain features exist which are not indicated in standard topographical maps. These are e.g.:

- reserved coastal zones, particularly areas reserved for tourist purposes
- military areas and installation
- areas containing land mines and other explosive war remains

Information on such features must be sought at the relevant Egyptian authorities, e.g. the Governorate in question or the military. The roughness length classification for wind resource assessment and the sketch planning of wind farms in the field during site visits, are severely limited in the Gulf of Suez by the existence of land mines and other explosive war remains. In general, it is not possible to visit areas which cannot be reached be ordinary roads.

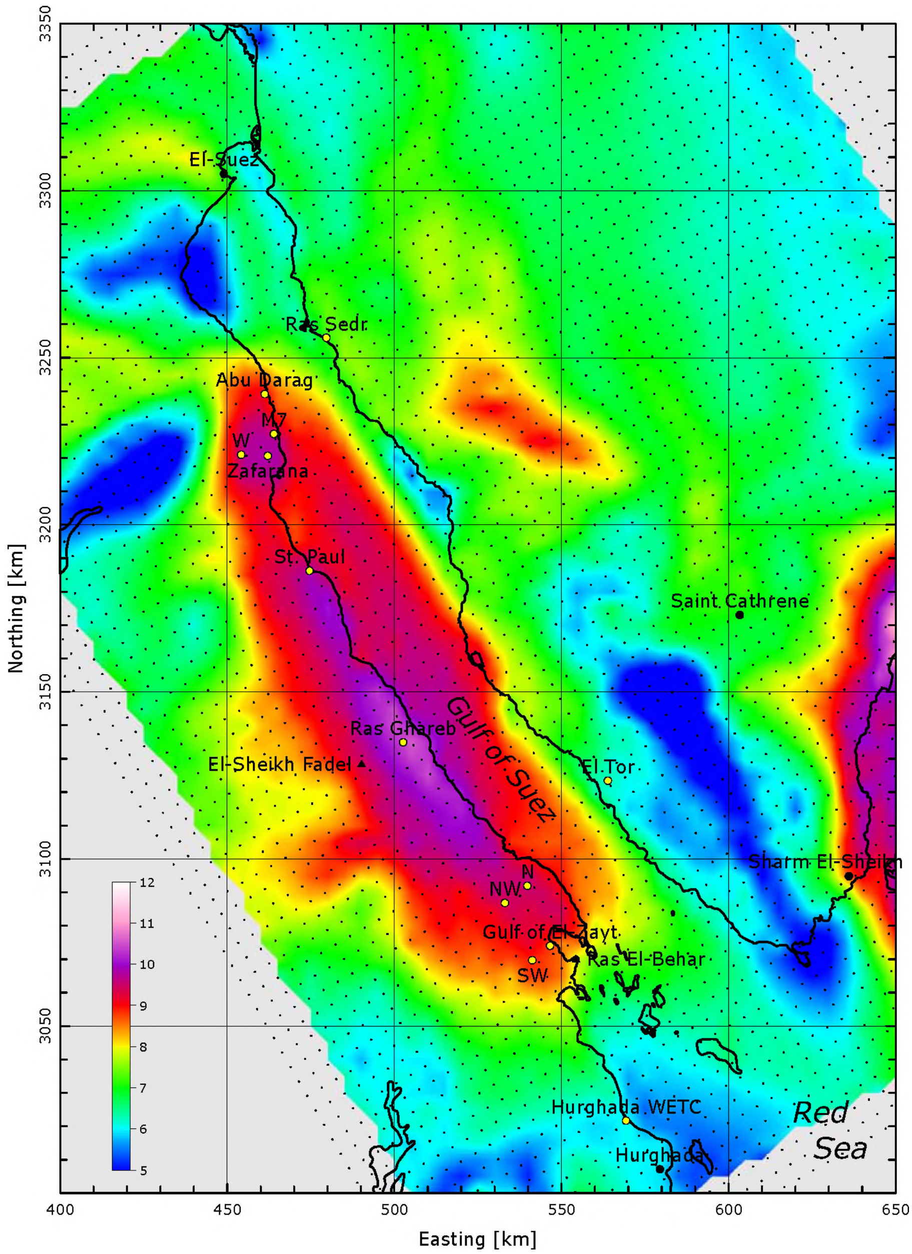


Figure 7. Modeled mean wind speed in ms^{-1} at 25 m a.g.l. over z_0 = 0.2 mm. The grid points of the KAMM model are shown by black dots. The wind atlas stations are shown with yellow symbols, other met. stations with black symbols.

3.3.4 Birds and Wind Turbines

Wind turbines – and in particular wind farms with many wind turbines assembled in a relatively small area – may possess a danger for the birds that live in the area or migrants that pass through. Overall, the potential negative impacts are of three types:

- Deterioration and fragmentation of habitats
- Disturbance
- Risk of collisions with the turbines

Furthermore, associated utility structures in particular power lines that connect the wind turbine farms with the electrical grid potentially possess a significant danger to birds as they can collide with the cables or get electrocuted when landing on the towers. Activities related to the wind turbines (maintenance and repair) may also have a disturbing impact on birds.

In the following brief accounts of the main types of potential conflicts will be addressed. This will be followed by summaries of some relevant studies that have been published regarding the bird-wind turbine issue.

Deterioration and fragmentation of habitats

The construction of wind turbine farms including access roads, electric installations etc. occupy relatively large areas of land. In particular this is the case when high numbers of medium size or large (650 kW - 1 MW or bigger) turbines are used. For instance, the distance between 1 MW wind turbines should be 500-750 meter to avoid a drop in performance from the turbines behind the first row.

The construction of a wind farm will directly result in both short-term (the duration of the construction phases) and long-term (at least the lifetime of the wind farm) habitat loss for breeding, resting and wintering birds (as well as animals and plants).

The impact of habitat loss depends on the bird species involved as well as the actual habitat type. In Egypt deterioration or loss of small areas of wetlands, for example, may have a disproportionately large impact compared to deterioration of widespread desert habitats. Special problem arises if a wind turbine farm is to be constructed at a site important to rare and endangered species.

Disturbance

Even if construction of a wind turbine farm does not result in a substantial impact on the habitat or food resources exploited by the birds, the turbines themselves may have an impact through their mere presence by scaring the birds away from the area. At least to some birds this can be an important factor. The degree of impact depends on the habitats where the turbines are placed and the species affected. In Egypt this could be a problem affecting birds such as bustards, which occur in open undisturbed habitats at the fringe of deserts. When wind turbines are placed in areas with breeding populations of ground dwelling birds some species avoid nesting within several hundred meters of the turbines, while others do not take notice of the wind turbines.

Collisions

Over the years the major concern of many impact assessments on wind energy schemes carried out in Europe and U.S.A. has focused on the collision risk (birds collide with the rotor blades or tower of the wind turbine and get killed).

Bird colliding with wind turbines have been recorded at both breeding and wintering areas and along migration routes but nearly all studies have been carried out in breeding and wintering areas and only little attention has been paid to wind turbines along migration routes.

Since one of the worlds major bird migration routes is passing through Egypt with large numbers of raptors, storks and other species sometimes occurring at very low altitudes, the bird-wind turbine collision issue is of special importance to Egypt.

Generally speaking, the number of bird fatalities is higher at wind turbines placed near the sea (or other wetlands) than at wind turbines further inland. For wind farms near the coast in the Netherlands it has been estimated that < 0.3% of the birds passing on migration at night would collide with a turbine while the proportion during the day is much lower (< 0,03%), Ref. [28]. However, the same study postulate that possibly as many as 1% of the birds that passes the Wind Farm will be killed by the turbines. This is because the number of casualties recorded is believed to be much lower than the actual number because predators remove the dead birds quickly and because the observers are not 100% efficient, Ref. [28].

Clausager and Nøhr, Ref. [14] concluded in their review on impact of wind turbines on birds that "some species, such as birds of prey, may have an increased risk of collision during their avian hunting. In situations of wind turbines located in areas with large concentrations of migrating birds the risk of collision may increase, but even in such cases the number of bird colliding has not been alarmingly high".

When discussing bird mortality it is important not only to focus on the mortality rates (deaths/turbine/year) or total number of fatalities per year in a wind resource area. Attention should also be paid to the long-term effects of increased fatalities, which can affect the viability of a bird population. Recent findings from the Altamont Wind Resource area in California suggest according to one model estimate that the 6,500 operating wind turbines in this area have caused a decline of the regions breeding population of Golden Eagle. By use of another model the estimate does not indicate a decline in the population, Ref. [17]. In another study in the same area fatality data were collected during 11 months at 414 turbine towers. This study indicated a mortality rate of only 0.15 bird death/turbine/year. Ref. [26].

Other utility structures associated with wind farms

The construction of a wind turbine farm usually requires a number of associated utility structures. Especially power lines that connect the wind turbine farms with the electrical grid potentially possess a significant danger to birds.

Power lines create two types of problems to birds; birds can collide with the cables or get electrocuted when landing on the towers.

<u>Collision</u> with overhead wires is a large problem in some areas where in particular certain groups of birds are very vulnerable. So far, only very few detailed studies of bird collisions with electricity structures have been undertaken in Africa.

Longridge, Ref. [18] found that flamingos, spur-winged geese and yellow-billed duck were particular susceptible to being killed or crippled by colliding with power lines along a narrow wetland in South Africa. South Africa is at the end of the long migration route of birds from Europe and contrary to what was previously thought large numbers of migrating White Storks are killed here by hitting power lines. In a recent South African study 24% of collision-related deaths reported involved this species. After White Stork the birds most often recorded killed by power lines in this study were cranes, bustards and flamingos, Ref.

[27]. Collisions with electricity structures have been identified as the single biggest cause of unnatural mortality in the endangered South African breeding population of Wattled Crane, Ref. [20].

Electrocution mainly appears to be a problem associated with certain types of distribution lines where the conductors are placed above the cross-arm of the tower. This makes it possible for large birds to touch a conductor with the extended wing when landing on the cross arm.

In the harbour at Port Sudan in Sudan overhead power lines of this type are known to have killed large numbers of migratory and sedentary birds of prey when they attempted to land on the poles, Ref. [22]. In the North-West Province of South Africa large numbers of the endangered Cape Griffon Vulture were electrocuted on 88 kV transmission towers before the design of the cross arm was changed from a pin-type insulators to suspended insulators, Ref. [27].

Studies of birds – wind turbine interactions around the world

Over the years several hundred papers and reports have been published on the bird-wind turbine issue. Most of the studies have focused on the problem with birds colliding with turbines. This has been examined in relation to a single specific wind turbine, wind turbine farms, certain groups of birds, foraging birds, breeding birds, birds on migration and so on.

As there are currently no plans of constructing off-shore wind turbine farms in Egypt in a foreseen time, and turbines are unlikely to be sited in cultivated land, the following examples of studies on bird – wind turbine issues will be limited to either:

- Deal with bird migration-wind farm issue in general.
- Focus on species that occur regularly on migration in Egypt (over land).
- Deal with the potential problems of placing wind turbines close to wetlands.

Studies on the bird migration-wind turbine issue – the Tarifa case

Much concern has been centered on a complex of wind turbine farms build in 1993 at Tarifa in southern Spain. At this site 268 wind turbines were initially constructed on a plateau in the mountains that face the Strait of Gibraltar. Very large numbers of migratory birds pass the Tarifa area including 60% of the entire Western European migratory raptor population. Close to Tarifa is also a rocky outcrop that serves as a vulture night roost where hundreds of vulture sometimes roost during the winter, see Pennequick cited in Ref. [19].

Following the construction of the wind turbines an alarming number of dead birds were found at the wind farm. This included several species that were protected by Spanish and European Union law (mostly birds of prey such as vultures and falcons) Ref. [19]. The victims were mostly killed when colliding with the turbines while others were killed by collision with power cables at the farm. It was found that in one year 106 birds were killed after colliding with turbines or the power lines connecting them to the grid (0.34 bird pr turbine per year) Ref. [21]. On top of that, only 1/3 of the wind turbines was monitored on a regular basis and only medium –size and large birds were studied. The real death toll could, in fact be much higher than recorded. The rate recorded was believed to be the highest death tool in the world for that number of wind turbines. However, it should be noted that a large percentage of bird deaths occurred at a specific number of turbines close to the mountain ridge. The impacts mainly involved Griffon Vultures and Kestrels but also several Eagle Owls, Lesser Kestrel and Short-toed Eagles were killed. Surprisingly, the majority of the birds killed (the vultures and the kestrels) were believed to be residents birds and the study revealed that the migratory birds, although passing close by, were not affected by the standing turbines.

The report prepared by Montes & Jaque, Ref. [21], included several recommendations to reduce the number of collisions among birds of prey and turbines. The two main actions were:
1. To remove the (few) wind turbines that causes the highest collisions risk.
2. To increase the threshold of the wind speed that causes the wings to start rotating.

The purpose of the second recommendation was to avoid situations where vultures due to little wind have difficulties in manoeuvring and therefore sometimes are forced into the slow rotating blades by the slope wind. Unfortunately, none of the suggested mitigating measures have been introduced and substantial numbers of vultures are still killed by the turbines every year, (Ramón Martí (SEO) in litt. 2000).

Dutch studies of the nocturnal migrants – wind turbine issue

The Dutch Institute for Forestry and Nature Research has commissioned a series of field studies of the impact of a small wind farm (18 turbines each of 300kW) placed close to the sea in the northern part of the Netherlands.

These studies included estimates of collisions of migratory birds at night using radar, passive image intensifier and thermal image intensifier. The migratory birds that passed the wind farm at night were mainly different species of passerines. Winkelman, Ref. [28], found that 0.05 dead or injured bird was recorded per turbine in operation per night in the migration period. This figure was calculated from a migration density of 1,640 birds passing the wind turbine farm at an altitude of 0-60 m (max. height of the turbine) per night, per 1,000 m along the front perpendicular to the flight direction.

From the number of collisions recorded, Ref. [28] Winkelman, calculated that app. 1% of all birds that passed the wind turbine farm at a height of 60 m or less are killed. This figure was about ten times higher than the number of birds actually found dead under the turbines. The difference was believed to be caused by the fact that (small) dead birds are difficult to find and that predators remove some birds before they are located.

Birds of prey and wind turbines – the Altamont Pass case

Around 1990 a very large wind turbine farm was constructed in the Altamont Pass, California. The facility lies just east of San Francisco Bay and contains about 7,000 wind turbines on 190 km² of rolling grassland.

Orloff and Flannery, Ref. [23], carried out a two-year study of the Altamont Pass wind energy production area commissioned by the California Energy Commission. The study area covered 16% of the wind resource area. During the study 43 bird carcasses were identified that may have been killed by wind turbines within the study area. Of these 19 were birds of prey. By extrapolating these data it was concluded that as many as 567 birds of prey may have died within the entire Altamont Pass wind energy production area. Most of the casualties were Red-tailed Hawk and American Kestrel but also included Golden Eagles. It was estimated that as many as 78 of the casualties were Golden Eagles. This figure has subsequently been verified by the wind industry of the Altamont Pass Wind Resource Area which each year reports 28-43 turbine blade strike casualties of Golden Eagle with more carcasses doubtlessly going unnoticed, Ref. [17].

A continuation of the original study by Orloff and Flannery, Ref. [23], gave some explanation for the high mortality recorded. Perching behaviour made species like Red-tailed Hawk and American Kestrel more susceptible to collision than others. However, the perching frequency cannot explain the relatively high mortality for Golden Eagle. Concerning this species it seems more likely that the flight behaviour during hunting has to do with the high number of collisions. Furthermore, the analyses of new mortality data confirmed the findings from the original report that both end turbines and turbines close to (within 500 ft of) canyons were significantly associated with mortality, Ref. [24].

To determine whether or not the death toll of Golden Eagles in the Altamont Pass Wind Resource Area may affect the population level a pilot study was initiated in 1994. Data from radio-tagged eagles suggested that at least 75% of the birds wintering in the Altamont Pass are residents, (Hunt et al. 1994). Nesting productivity and success in the region were higher than normal for Golden Eagles and nesting density in parts of the study area was among the highest reported for the species. The pilot project was followed by a four-year study. To estimate survival rates 179 eagles were tagged with radio transmitters equipped with mortality sensors and expected to function for at least four years, Ref. [17]. Of 61 eagles recorded dead, 23 (38%) fatalities were caused by wind turbine blade strike, and 10 (16%) by electrocutions on distribution lines (outside the WRA), Ref. [17]. However, additional fatalities (31% estimated) were not recorded because the turbine blades had destroyed the transmitter (including the mortality sensor). It is still too early to make clear statements about the impact on the Golden Eagle population, Ref. [17]. Additional data collection over the next few years should provide a better understanding of to what extent the Golden Eagle is being impact in the Altamont Pass wind farm, Ref. [17].

Alongside the population study of Golden Eagle in the Altamont area, new studies have recently been initiated to determine how behavioural factors may contribute to increased risk when individual birds encounter wind turbines. The study has so far included fatality data collection at 414 turbine towers where 95 bird fatalities were recorded (plus one bat) during 11 months, Ref. [26]. These initial results indicate a mortality rate of 0.15 bird deaths/turbine/year. Golden Eagles, Red-tailed Hawks and American Kestrels were killed more frequently than Turkey Vultures and Ravens, even though the latter two species are more abundant in the Altamont area. The data confirm that the relative abundance of species does not predict the relative frequency of fatalities per species. Some species are apparently more susceptible than other to the risk posed by wind turbines, assuming carcass detection probabilities are equal per species. Another (surprisingly) finding is that tubular towers appear to represent as significant a risk to birds as do horizontal-lattice turbine towers.

Danish study of habitat loss – wind turbines

The effects of wind turbines and other physical landscape elements on field utilisation by wintering Pink-footed Geese were studied in a Danish farmland landscape (Larsen & Madsen 2000). Within the study area the geese were feeding on pastures, which together with cereals were the main crop types. Apart from wind turbines a variety of potentially disturbing landscape elements was present, e.g. power lines, windbreaks, roads and settlements. Patterns of field use were assessed by measuring goose dropping densities along transects perpendicular to wind farms (with turbines in clusters and in lines) and other landscape elements. Local effects were expressed in terms of 'avoidance distance', i.e., the distance from a given landscape element to the point at which 50% of maximal dropping density was reached. The avoidance distance of wind farms with turbines in lines and in clusters were ca. 100 m and ca. 200 m, respectively. The geese did not enter the area between turbines within the cluster. At the landscape level, the combined effect of physical elements other than wind turbines caused an effective loss of 68% of the total field area (40 km^2). The wind turbines caused an additional loss of 4% of the field area. However, of the remaining area available to geese (13 km^2), wind turbines caused a loss of 13% of the total area. The habitat loss per turbine was higher for the wind turbines farm with turbines arranged in a large cluster that for wind farms with turbines in small clusters or lines. This difference was mainly due to the fact that wind farms in small clusters or with a linear layout were generally placed close to roads or other elements with existing associated avoidance zones, whereas the large cluster was placed in the open farmland area. The avoidance zones associated with physical elements in the landscape do not take into account possible synergetic effects and, hence, the actual field areas affected are likely to be minimum estimates.

3.3.5 The birds of the Gulf of Suez area

The resident birds of the Gulf of Suez area mainly include species associated with the different desert habitats, the oasis and the marine environment (the coast and coastal islands of the Red Sea). However, by far the largest number of the birds that occur in the Gulf of Suez area are non-breeding migrants, which pass through the area during spring and autumn. The Gulf of Suez is situated along one of the major flyways for birds breeding in Europe and Asia and wintering in Africa. Very large numbers of birds therefore migrate through the region twice a year.

Birds migrating through the area can be divided into three main categories:

- Large birds such as birds of prey, storks, cranes and pelicans that migrate during the day. These birds mainly exploit up-currents produced by convection (thermals) and raising air over mountains (orographic airflow) to provide lift to maintain or gain altitude with a minimal expenditure of energy. Over land these "soaring and gliding" migrants usually follow well-defined corridors where thermals or raising air over mountains are particularly stable. Where several migration paths meet or where the path's become particularly narrow due to topographical features, the birds congregate in huge numbers. In Egypt, such "bottlenecks" occur where the birds follow narrow mountain ridges, coastlines or at capes that serve as stepping stones for birds that cross the sea.
- Small birds that mainly migrate at night. These birds move over a broad front across the Mediterranean Ocean or over land from the Middle East. Many of the birds rest during the day, mainly at oasis or along the Mediterranean coast. These birds almost exclusively use a "flapping fight" (constant active flight opposed to soaring or gliding on extended wings).
- Waterfowl (ducks, shorebirds, gulls and terns) migrate mainly during the day and occur exclusively along the coast of Egypt and at inland wetlands.

Diurnal migration along the Gulf of Suez

A field study of the bird migration spring and autumn along the western shore of the Gulf of Suez was carried out as part of this project. The study focused on soaring migratory species as they are believed to potentially be particularly vulnerably to collide with wind turbines because they at certain sites occurs in very high numbers at low altitudes. Furthermore, these large birds have extremely poor maneuvering abilities in strong wind and are in some situations incapable to steer round a stationary obstacle (wind turbine). A comprehensive account of this study is published in a separate report, Ref. [2]. The following summary is meant to give a picture of the magnitude and type of the bird migration and movements in the area and to illustrate the potential problems envisaged.

Spring migration

In spring when the birds move from tropical Africa towards Europe, Russia, Western Asia and the Middle East most of the soaring migrants that pass Egypt follow the mountain chain that runs parallel to the Red Sea. This includes about 2-3 million raptors, 500,000 storks, 50,000 cranes and 25,000 pelicans, Ref. [25] and Ref. [2].

The soaring migrants that pass Egypt on spring migration follow two main routes:

1. Along the Red Sea Mountains northwards to Suez and from there in a north-easterly direction towards Israel.
2. North along the Red Sea Mountains until Gebel El Zeit where the birds turn north-east and cross the Gulf of Suez to reach the mountains on the Sinai and continue northbound towards Israel.

Some migrants may also cross the Gulf of Suez at various points between Gebel El Zeit and Suez.

Autumn migration

Like in spring the soaring migrants follow two main migration routes when passing eastern Egypt:

- A northern route that passes over (or just north of) the town of Suez. When reaching the mountains southwest of Suez the birds follow the Red Sea Mountains southwards.
- A southern route via the Sinai peninsula, across the Gulf of Suez and southwards over the Red Sea Mountains.

Nocturnal migrants

This includes the majority of small birds such as warblers, flycatchers, finches, pipits, buntings etc. that spend the winter in tropical Africa. The number of species that pass Egypt during migration is high and the total number has been estimated at 800 million individuals, Ref. [16]. These birds arrive over land from Israel or over sea directly from Greece and Turkey.

The nocturnal migrants do not form flocks as such and are not following specific corridors. Typically they fly alone or in loose groups proceeding over a broad front. A radar study of the flight altitude of migrants passing Egypt at night showed that 21% of all birds flew below 100 m, Ref. [16]. Assuming that 800 million birds pass through Egypt during an autumn season (the number is somewhat lower in spring) and assuming that the birds fly over a broad front, it has been estimated that the number of birds flying at altitudes below 100 m is 16,000-65,000 per night per kilometer, Ref. [16].

3.3.6 Data for Assessment of Environmental Impact

The need for data to make an Environmental Impact Assessments in the Gulf of Suez area largely depend on if it is a partial or full assessment that is to be prepared. A question which will be decided as a result of following the Specific Guidelines for Environmental Impact Assessment of wind turbines and wind farms in Egypt - EEAA Specific Guidelines, Ref [9].

If the case requires a partial EIA, the information presented in the "Bird Migration Atlas of the Gulf of Suez", Ref. [2], will be sufficient in most cases to cover data on bird migration. If a full EIA is to be prepared a field survey must be included to collect data from the specific site where the proposed wind farm is to be build. Since birds on migration will be the main aspects to cover in a desert area with very few resident birds, the field-work must be scheduled to cover the two migration periods (spring and autumn).

3.4 GIS and the wind farm planning process

3.4.1 Mapping by Geographical Information Systems (GIS)

Experience gained in the Wind Atlas for Egypt (and other) projects suggest that it could be advantageous to employ a Geographical Information System (GIS) in the wind farm planning process in Egypt. Results of the wind measurement programs and the wind flow modeling (WAsP and KAMM) in the Gulf of Suez, as well as the results of the Bird Migration Atlas and other Environmental Impact Assessments can all be referenced to coordinated points in a map or GIS domain. Likewise, many of the constraints for wind farm planning has to do with the physical-geographical features of the terrain and land-use in the domain.

Data and model results already exist in digital form, in a number of different file formats, which are determined by the observation techniques, software tools or models. By transforming these data and results to common, standardized formats that can be imported into a GIS system, it will be possible to view, analyze and model all this information in a number of ways that would greatly enhance and improve the wind farm planning process.

Below proposed specifications of the hardware and software needed for implementing a GIS system is presented.

3.4.2 Overview of GIS Hardware and Software

Recommended hardware

In addition to standard PC equipment, the following hardware is recommended:

- a digitizing tablet, size A1
- a color printer, size A3
- a color scanner, size A3

The digitizing tablet is used to transfer information from standard topographical map sheets to digital files of the same information that can be imported into the GIS and other software packages (WAsP). Most map sheets are smaller than size A1, which is therefore considered the maximum recommended size. The Wind Energy Department at Risø has an A0 digitizing tablet; however, it is our experience through more than 15 years of operation that this size is almost never utilized to its full extent. Also, the A1 size tablet is much more manageable and practical; it also costs less.

The color printer is used to print results from the GIS system and other software packages such as WAsP and Surfer (from Golden Software). It is essential that information covering the entire GIS domain – such as elevation and slope maps, wind resource maps, and other background information – can be printed together with the wind farm layout and other relevant point and line features. Therefore, a color printer is preferred to a color plotter. An A4-size color inkjet printer may initially suffice, but an A3-size (or even larger) color printer is recommended for future use. Poster-size (A2 and larger) prints can be printed at a specialized shop or company.

The color scanner is used to scan background information for the GIS system and other software. Examples are aerial photographs and topographical and thematic maps. The bitmap files may be used directly in the GIS or may be used with e.g. the WAsP map editor or Didger to digitize information that can be transferred to the GIS (and WAsP). Size A3 is considered the maximum feasible size for in-house use; if larger sizes are occasionally needed, these may be scanned at specialized companies or institutions.

Recommended software

In addition to standard office and wind resource software, the following software is recommended:

- GIS software package and training
- 3D terrain analysis and graphics package
- software to operate the digitising tablet

The GIS software is of course the heart of the GIS System for Wind Farm Planning. Numerous software packages exist, from shareware packages that can be downloaded freely over the internet, to comprehensive, professional, commercial systems. For the purpose of implementing a system for wind farm planning from scratch, it would be advisable to choose a mainstream, commercial software package with lots of import and export facilities – and lots of utility programs and macros available from other users. This would ensure maximum compatibility and benefit from existing data. As an example, the most popular GIS system in the world, ArcView from ESRI, would be an investment of about USD 1,500 for a single-user license of the basic GIS package (version 8.1). The ArcView system is modular in nature and may later be upgraded with e.g. Geostatistical Analyst (USD 2,500), Spatial Analyst (USD 2,500) or 3D Analyst (USD 2,500) – if and when required.

The 3D terrain analysis and graphics package is used to transform vector terrain data (height contours and spot heights) to elevation and slope grids that can be imported into the GIS. It can also process and display WAsP resource grid files and derived grids of e.g. wind distribution parameters. Surfer is a reasonably priced, yet powerful, software package for this purpose, and both NREA, Risø and Hedeselskabet A/S have lots of data in Surfer formats already. Version 7 (or later versions) is strongly recommended.

The digitising tablet must be operated through a digitising program and a Wintab driver. Golden Software's Didger has been used by NREA and Risø for several years and this program will suffice for most purposes. Didger can also scan or import bitmap images; these can further be geometrically adjusted in order to fit into the co-ordinated GIS domain. Version 3 (latest update) is strongly recommended.

Drivers for the digitising tablet, the printer and the scanner are usually included in the delivery of the hardware. Drivers for most digitising tablets may also be acquired from http://www.vtablet.com/ at a reasonable price.

4 Wind farm planning – siting, sizing and layout

4.1 Wind Farm Site Selection

4.1.1 Some definitions

- Siting:
  Investigation of an area/region/district with the purpose of selection of the location (site) for a wind farm
- Sizing:
  Decision on the size of wind farm in terms of land area and installed capacity
- Wind farm layout:
  The configuration and arrangement of the individual wind turbines' locations within the selected site – as a result of an optimisation at given assumptions and constraints using agreed criteria
- Micro-siting:
  Determination of exact position of each wind turbine in a wind farm; coordinates (x, y down to 1 m) on a detailed map as well as survey and marking in the ground on-site

4.1.2 Planning

The initial phases of the planning process of a wind farm project involves the determination of the size of the wind farm in view of constraints with respect to:

- planning act and other legislation
- local and national development plans and policies
- land availability, access and transport infrastructure
- power system – present situation and expansion plans
- wind turbine technology
- financing/funding
- electricity market and PPA
- environmental impacts
- institutional capacity

Economic and financial optimum size for society and investors at the given conditions may vary for different sites, so sizing and siting should be seen as integrated activities. Furthermore, sizing certainly involves aspects that may not easily be quantified in monetary terms.

In addition to the sizing, the planning involves site selection for the wind farm – a procedure which most often degenerates to comparison of selected candidate sites with respect to among other issues:

- compatibility with project objectives and development plans, which may involve other than economic drivers
- potential wind energy production
- environmental "costs and benefits"
- sustainability, assumptions, uncertainties and risks
    - production estimation
    - availability of land, infrastructure, institutional framework, human resources, equipment
    - community and power system development as well as authorities' attention and priority
    - investments, investors, economic and financial data and assumptions
    - design safety, interference, reliability and lifetime
    - wind farm and power system operation and maintenance
- economic and financial viability and attractiveness

In practical terms, the siting and sizing exercise is carried out through implementation of a pre-feasibility study, which at an early stage in the project cycle analyses all essential feasibility aspects as indicated above – with the main purposes of serving as input to:

1. initiation of the negotiation of financial arrangements,
2. the local scoping process and hearings
3. obtaining planning authorisation and approvals, including nature conservation – i.e. Environmental Impact, etc

4.2 Terrain Description for Wind Resource Assessment

The terrain features that influence the wind flow close to the ground – and thereby determine how the regional wind climate is transformed into the site-specific wind resource – are often categorized in three broad classes:

- The geometry of the terrain surface (elevation, slope, ruggedness, etc.)
- The surface characteristics of the terrain (land use or roughness length)
- Near-by sheltering obstacles (houses, trees, shelter belts, etc.)

4.2.1 Terrain elevation

An accurate description of the overall geometry of the terrain surface is a pre-requisite for reliable modeling of the wind flow over the terrain. The most important feature is the elevation of the terrain surface above mean sea level. An example of an elevation map of a wind farm site is given in Figure 8.

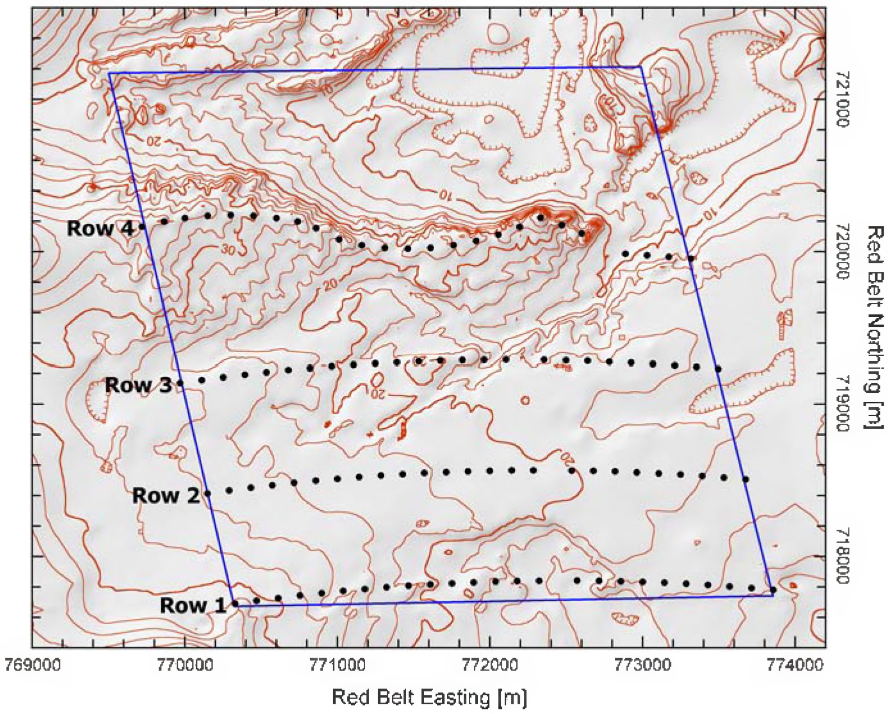


Figure 8. Elevation map of the NREA/Danida wind farm site close to Zafarana. The map was established by a site-specific survey employing kinematic GPS techniques. The height contour interval in the map above is 2 m, but it is possible to draw 1-m contours as well. Four sample wind farms, each consisting of 25 600-kW wind turbines, are indicated by black dots.

In general, it is possible to establish digital maps with 10-m height contours in the Gulf of Suez. If spot heights are considered as well, it may be possible to detail such maps in certain areas, but if a more detailed elevation description is needed, a site-specific survey of the terrain is required.

The influence of the detail in the elevation description on the modeling of the wind flow – and thereby the estimation of the annual energy production – can be estimated using different maps of the wind farm area; with different height contour intervals. An example is given in Table 3, where predictions for the four different wind farms shown in Figure 8 have been calculated for maps with different height contour intervals: 1, 2, 5, 10 and 20 meters. The regional wind climate and wind turbine type used for the predictions are the same in all scenarios. The hub height of the turbine is 40 m a.g.l. and the wake interactions between the four farms and between the wind turbines in each farm have not been taken into account.

Table 3. Estimated annual energy production for four different 15-MW wind farms, for different height contour intervals in the digital terrain model of the wind farm sites. The AEP production figures given for each farm correspond to an index of 100 for the most detailed terrain description (right-most column).

Wind farm	AEP [GWh]	Height contour interval in site map 20 m	10 m	5 m	2 m	1 m
Row 1	70.217	99.4	99.7	99.7	99.8	100.0
Row 2	70.772	99.4	99.6	99.7	100.0	100.0
Row 3	70.883	98.5	99.0	98.9	99.8	100.0
Row 4	74.681	94.1	96.6	98.6	99.8	100.0

In the flat areas (Row 1 and 2), the height contour interval has little influence on the estimated AEP. In the more hilly areas (Row 3 and 4), the contour interval has some influence on the estimated AEP, especially in more hilly terrain (Row 4). With a small height contour interval, the hills and valleys (wadis) become more well-defined and the speed-up/slow-down of the modeled winds more pronounced. This leads to higher estimated AEP values because the wind turbines are situated on top of the hills and ridges. In the case of the Row 4 wind farm, the AEP seems to be underestimated by about 3-4% if the standard 10-m contours are used for the flow modeling. In all cases, a contour interval of about 2 m seems to be sufficient for accurate flow modeling.

4.2.2 Terrain slope

It becomes increasingly difficult to model the wind flow accurately when the terrain gets steeper. Linearised flow models, like the WAsP BZ-model, require that the flow is attached to the terrain surface and that wide-spread separation does not occur. As a rule of thumb, separation occurs at slopes of about 30% (~17°) and steeper. Therefore, it is often necessary (though rarely in the Gulf of Suez) to estimate the slope of the terrain surface. This can be done by calculating a grid of spot heights from the height contour map and then calculate the terrain slope in each grid point. The resolution of the grid should be about the size of the rotor diameter or smaller.

Figure 9 shows a terrain slope map for the wind farm site depicted in Figure 8. A 25-m grid has been established from the height contour map; the terrain slope is calculated for each grid point and plotted as a map of terrain slope. The hills, ridges and wadis can easily be identified even though the slopes are generally small, about 3-4°. Only the larger hills and ridges are significantly steeper, with slopes of up to about 17°.

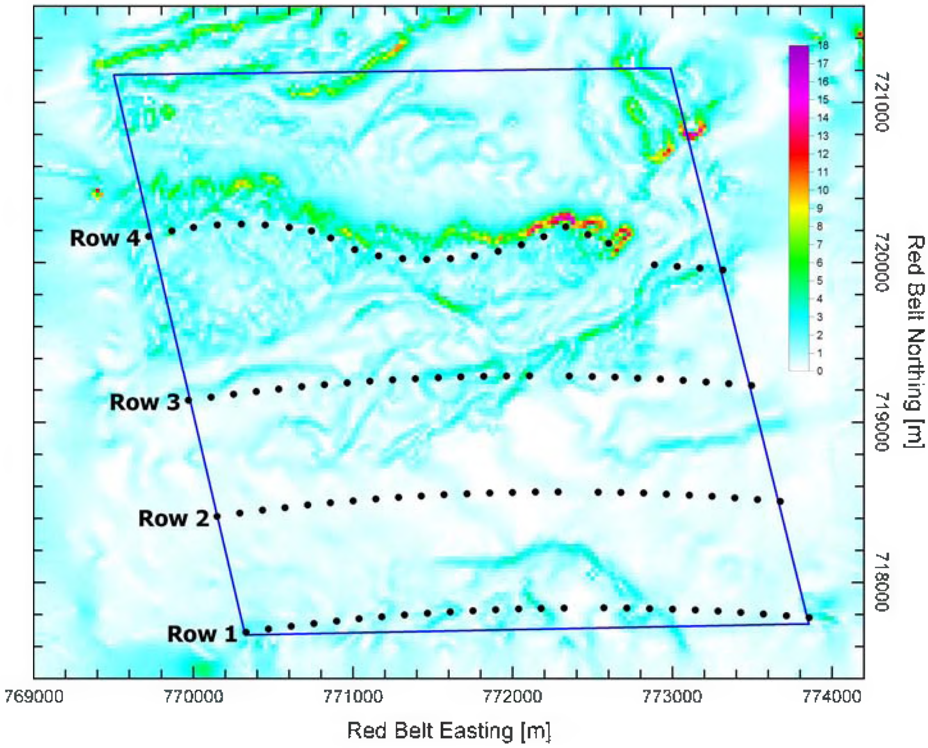


Figure 9. Slope map of the NREA/Danida wind farm site close to Zafarana. The map shows the maximum slope [deg] of the terrain, irrespective of the slope direction. The grid cell size used for the slope calculations is 25 m.

4.2.3 Terrain ruggedness

If large parts of the terrain are steeper than about 30%, it may be necessary to evaluate the complexity or ruggedness. One objective measure of the steepness or ruggedness of the terrain around a site is the so-called ruggedness index or RIX, defined as the percentage fraction of the terrain steeper than some critical slope, say 0.3, Ref. [15]. This index was proposed as a coarse measure of the extent of flow separation and thereby the extent to which the terrain violates the requirements of linearised flow models such as the BZ-model. The recommended operational envelope of the WAsP flow model thus corresponds to small (~ 0%) RIX values.

Based on the limited experience available, landscapes may be characterised by the following RIX values: flat and hilly 0%, more complex about 10% or less, mountainous from about 10 to 50% or more. The RIX values of a specific met. station, turbine site or wind farm site situated in complex terrain can be calculated using the WAsP program. A ruggedness index map may help in evaluating the site predictions.

The ruggedness index has also been used to develop an orographic performance indicator, ΔRIX, for WAsP-predictions in complex terrain, Ref. [9] and Ref. [12] – where the indicator is defined as the difference in the percentage fractions between the predicted and the reference site. This indicator may provide the sign and approximate magnitude of the prediction error for situations where one or both of the sites are situated in terrain well outside the recommended operational envelope.

4.2.4 Land-use and roughness length

An accurate description of the land use and roughness lengths of the terrain surface is another prerequisite for reliable modeling of the wind flow over the terrain. The most important land-use classes in the Gulf of Suez are: the sea surface, the desert surfaces, the mountains and the built-up areas. Natural vegetation and agricultural areas play little or no role here. The coastline represents the most pronounced and important change of roughness and this should always be taken into account.

The overall land-use pattern of a particular area can be established from topographical maps, aerial photographs or satellite imagery. Because of the existence of land mines, field mapping and verification are limited to what can be seen from public roads or by climbing met. masts or buildings.

The most common land-use type, corresponding to the background roughness length, consist of desert surfaces. It may be difficult to estimate the roughness length of such surfaces; however, it should be borne in mind that this estimate is most critical if the met. mast is low and less critical the higher the mast. Preferably, the anemometer used for predicting the wind turbine production should be mounted at a height comparable to the hub height of the proposed wind turbine.

The influence of the detail and accuracy in the roughness description on the wind flow modeling can be illustrated using different maps of the wind farm area; with different roughness classifications. An example is given in Table 4, where predictions for the four different wind farms shown in Figure 8 have been calculated for maps with entirely different roughness classifications: land only, land/sea only and the full description. The regional wind climate has also been recalculated since the met. station is in the same map. However, the wind turbine type used for the predictions is the same in all scenarios. The hub height of the turbine is 40 m a.g.l. and wake interactions between the four farms have not been taken into account.

Table 4. Estimated annual energy production for four 15-MW wind farms, for three different roughness descriptions in the digital terrain map. The production figures given for each farm correspond to an index of 100.

Wind farm	AEP [GWh]	Roughness description Land	Coast	Full
Row 1	70.217	102.6	97.6	100.0
Row 2	70.772	102.4	97.5	100.0
Row 3	70.883	102.5	97.6	100.0
Row 4	74.681	102.6	98.0	100.0

In the "land" case, the entire modeling domain consists of a uniform land surface with a roughness length of 2 mm; here the power production is overestimated somewhat. In the "coast" case, the surface is divided in two classes only: land (2 mm) and sea; here the AEP is underestimated. Finally, in the "full" case, a detailed roughness length description based on interpretation of aerial photographs and site visits is employed.

4.2.5 Sheltering obstacles

Sheltering obstacles in the Gulf of Suez are almost exclusively man-made structures like houses and walls. However, the height of typical obstacles and their distance to possible wind farm areas suggest that it will only rarely be necessary to model these structures as obstacles. Instead, the towns, villages and summer cottage areas are treated as adding to the roughness of the areas in question.

The following rule of thumb may serve as a guideline when deciding whether to include obstacles in the terrain as sheltering obstacles or as roughness elements:

- if the point of interest (anemometer or wind turbine hub) is closer than about 50 obstacle heights to the obstacle and closer than about three obstacle heights to the ground, the object should probably be included as an obstacle. In this case the obstacle should not at the same time be considered as a roughness element.

- if the point of interest is further away than about 50 obstacle heights or higher than about three obstacle height, the object should most likely be included in the roughness description.

A wind turbine with a hub height of 40-50 m a.g.l., sited well away from buildings, will therefore rarely experience shelter effects.

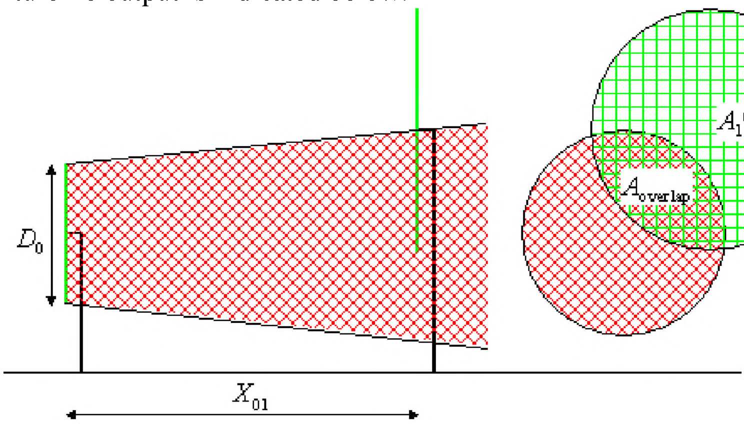
4.3 The wind farm model – array efficiency and energy production

To calculate the power production of a wind farm, taking the turbine wake losses into account, you need the predicted wind climates for the sites and the following turbine characteristics:

- The wind turbine hub height [m] and rotor diameter [m]
- The power curve [ms-1 and kW]
- The thrust coefficient curve [ms-1 and dimensionless]

The wind farm model implemented in the WAsP PC-software package (PARK) is described here. The WAsP model, supporting mixed-turbine-type wind farms, is based on a mathematical model of the wake behind a wind turbine, developed by N.O. Jensen (1984), Ref [38], and later extended to actual wind farms by Katic et al. (1986), Ref [39]. This model uses momentum-deficit theory to predict the flow field in a very simple way: the wake is assumed to expand linearly behind the rotor. Thus, the only variables are the initial velocity deficit at the start of the wake, evaluated from the Ct -coefficient of the turbine at actual wind speed, and the wake decay constant, which is the rate of expansion (break-down) of the wake.
The model assumes the centre-line of the expanding wake to follow the terrain, and the different hub heights and rotor diameters are taken into account by the overlapping fraction of a wake with a down-wind rotor plane. Due to the simplicity of the model the terrain must be relatively homogeneous in order to prevent large speed-up effects etc.

The flow field and wind farm geometry used by the model to calculate wind turbine output is indicated below.



The effective wind speed deficit at the down-wind wind turbine ("1") is calculated using the following equation

$$\delta V_{01} = U_0 \left(1 - \sqrt{1 - C_t}\right) \left(\frac{D_0}{D_0 + 2kX_{01}} \right)^2 \frac{A_{overlap}}{A_1^{(R)}}$$

where U_0 is the undisturbed wind speed at the up-wind turbine ("0") with rotor diameter D_0, Ct the thrust coefficient, X_{01} the downwind horizontal distance between the wind turbines and k is the wake decay constant.

The thrust coefficient

The thrust coefficient curve may be difficult to find in standard technical data; however, all wind turbine data files supplied with WAsP includes thrust coefficient data. It can be computed by a rotor simulation program, estimated from data for similar wind turbines, or measured directly as tower bending moment. The thrust coefficient Ct is related to the thrust force F_T, ρ being the density of the air, as:

$$C_t = \frac{2F_T}{\rho \frac{\pi}{4} D_0^2 U_0^2}$$

The initial wind speed reduction from U_0 to V, when passing the rotor plane, is related to Ct by: $(1\text{-}Ct) = (V / U_0)^2$.

4.4 Wind Farm Layout

The development and optimisation of wind farm layouts is an exercise necessary for project assessment, project engineering and project implementation. In early phases during project preparations, the assessments aim at establishing the feasibility of the project at an acceptable level of uncertainty, whereas project engineering and implementation has to decide the final design and therefore requires an optimisation process according to best practices.

The wind farm layout may be determined according to different principles. No single layout concept is universally acknowledged as ideal and preferred, and no universally true automatic method to determining optimal wind farm layouts is therefore available. There are tools that can assist the analyses and could or should be applied as a part of the development and optimisation exercises, but there is no way around human judgment – at least when it comes to aesthetics and visual impact.

The general approach is to develop different candidate layouts and prepare sketch design and costing to the level of detail and accuracy required. These candidate layouts may be prepared using the tools available with more or less human judgment involved. The comparisons should then always be done on a common basis with one and the same set of tools and assumptions.

4.4.1 Recommended approach

1. Find or determine basic assumptions, information, parameters and input data. Such data may be found from previous work and projects or given by developers and authorities e.g. through planning guidelines. General planning tools such as the Wind Atlas for the Gulf of Suez 1991-2001, Ref. [1] and the Bird Migration Atlas for the Gulf of Suez, Ref. [2] supports the planning process. Information and input data necessary, include:
    - site – land available for the given wind farm
    - wind farm size (MW)
    - wind conditions – wind resource assessment, design winds and turbulence according to IEC61400
    - digitized topographic data and maps for the site and its surroundings – preferably up to a 10km distance from the site (at least to the north, which is upwind for the prevailing wind direction)
    - information on soil conditions, wadis, etc
    - wind turbines – type, size, hub height, rotor diameter (D), Power curve, thrust coefficient curve (C_T) – performance to be specified at local climate and dust conditions
    - requirements to structural safety, minimum spacing at the given wind climate (update technology specs)
    - electric power system network – existing and expansion plans, including interconnection possibilities and constraints
    - physical planning requirements such as archaeological and historic preservation sites, nearby airport obstacle limits, electromagnetic interference, limitations due to known installations and planned developments, including reservations of and restrictions on land for other purposes such as
        - reservation of coastal areas along the Gulf of Suez for tourist purposes, and
        - corridors for pipelines
    - other constraints and requirements by authorities due to social considerations, nature conservation and the environmental impacts, which at the Gulf of Suez includes
        - impacts on flora and fauna – especially bird migration,
        - acoustic noise,
        - visual impact, and
        - erosion

2. Develop candidate wind farm layouts respecting conditions and requirements assumed

3. Compare candidate layouts with respect to optimisation criteria, including information regarding:
   - wind energy production estimation
   - investment budget
     - sketch designs of electric grid interconnection as well as associated control and monitoring systems
     - sketch designs of wind turbine foundations, civil works and access roads
     - project implementation plan (wind turbine erection, etc) facilities and conditions
     - O&M facilities and conditions
     - land requirements and costs

   - power system performance modelling and power purchase agreement (PPA)
   - sustainability
   - environmental impact
   - cost-benefits for investors and the society
   - economic and financial analyses

4. For large wind farms improved on-site "site calibration" wind measurements for a few months to ensure accurate performance of wind resource assessment modeling across the site may be necessary. This exercise will minimize uncertainites in the wind farm energy production estimates for the different candidate layouts, and it will enable optimal micro-siting.

4.4.2 Wind farm layout concepts

The candidate wind farm layouts may be developed according to various principles and concepts, some of which are listed and briefly described below.

1. Rows in straight lines or curved

   Most often the optimum layout will be
   - rows along terrain features with "speed-up" effects (ridges, coast-lines, etc.)
   - rows perpendicular to prevailing wind direction (energy-wise)

   The layout should be arranged with
   - parallel rows
   - same distance between wind turbines in different rows
   - distance between rows larger than distance between wind turbines in row in order to increase energy output if in wind climate with prevailing wind direction, whereas visual impact has been found better in layouts with identical spacings between rows and wind turbines in rows
   - individual wind turbine located to minimize wake from upwind wind turbines (e.g. for close row-spacings by displacing rows ½ the distance between wind turbines)

   Spacing of wind turbines in a wind farm is given in non-dimensional form relative to the wind turbine's rotor diameter, D. As an example, $5D$ x $10D$ would mean 5 rotor diameters spacing between wind turbines in a row and 10 rotor diameters spacing between the rows.

2. Small clusters of wind turbines (e.g. 2-8 wind turbines)

   Clusters could be arranged in simple geometric shapes/patterns, e.g. as 3 wind turbines in a row or in an equilateral triangle. Otherwise same rules apply as for rows.
   Clusters are generally easier to integrate in the inhabited rural landscape, but may not be applicable for the Gulf of Suez and only in case development for one reason or another is divided into small wind farms

3. "Randomised" layouts
   The detailed coordinates of the wind turbines have a random element, so that no simple lines, curves, shapes or patterns can be seen. It might be determined from automatic routines such as WindFarmer. Generally this type of layout gives complex wind farm infra-structure, but primarily for aesthetic reasons it is often applied in the UK. However, for the same reasons it is not allowed by e.g. the authorities in Denmark.

The size of wind turbine plays an important role in the wind farm design, and is in fact often very directly linked to the layout optimization. The larger the wind turbines, the fewer the wind turbines, and the simpler and less complex the layout. For larger wind turbines, it is easier to determine the layout in hilly or complex terrain, and it is generally viewed as more calm and more visually acceptable, but due to size visible at larger distances.

4.4.3 Micro-siting – procedure during detailed design

During project implementation and as a preparation to the construction phase, a micro-siting exercise has to be carried out based on detailed information on wind conditions and wind resources across the site, as well as all other constraints (such as e.g. crossing pipelines in the ground or minimum distance to individual houses) on the chosen site.

Below please find an indication of some recommendations:

- Double-check all wind farm layout assumptions in the site
- Fine-tune wind farm layout
  - using detailed maps, e.g. 1:5000 with a height contour interval of 1-2 m.
  - apply exact definition of all constraints, e.g. site limits, position of any house, power lines, sub-stations, pipelines, site facilities, site infrastructure, etc.
  - allowing location of meteorological masts for power performance verification, e.g. according to IEC.
  - on-site soil investigations, including location of wadis
  - assess the visual effect, e.g.
    - wind turbines follow the landscape
    - equidistant spacing
  - respect conditions in planning authorization and ensure acceptable environmental impact
- Determination of exact position of each wind turbine in the wind farm; coordinates (x, y in m) on the map as well as surveyed and marked in the ground on the site.

4.4.4 Layout of wind farms in the sandy desert along the Gulf of Suez

This subsection illustrates the proposed procedure. As part of the layout optimization for a wind farm consisting of 100 600-kW wind turbines at Zafarana, an analysis of the sensitivity to spacing and density of wind turbines was carried out for the actual site in question.

The site is rather typical for the Gulf of Suez with respect to wind climate and terrain, and the procedure seems applicable for most of the flat and hilly sandy desert areas along the Gulf of Suez.

The flat parts in principle allow any spacing of wind turbines, whereas the hilly parts invite wind turbines to be located to the degree possible in rows on any east-west ridges with a spacing between wind turbines and rows similar to what is recommended for the flat land.

The wind climate at Zafarana has an east-west gradient, which is not the case all along the Gulf of Suez. Where an east-west gradient in the wind resource exists a similar analysis of the possible benefits of exploiting the higher wind resource to the east by reducing the spacing both between wind turbines in the rows and between rows (increasing the wind turbine density) may be recommendable. However, two important factors must be taken into consideration:

1. The smaller the spacing between wind turbines, the larger the fatigue loading from the wind from upwind wind turbines. Wind turbine design should always be site specific and for the actual layout built at the actual wind climate (e.g. for a spacing of 3 rotor diameters (3D) or smaller in the rows, it may become critical to a standard wind turbine depending on the wind speed and frequency of occurrence of wind along the rows).

2. At very small spacing between rows and wind turbines in rows combined, the flow models determining the wind farm wake losses are not very well validated and uncertainties on Annual Energy Production (AEP) estimates therefore increase. E.g. the PARK model built into the WAsP program package seems to work well for relatively few rows of wind turbines with a spacing of $5D$ x $10D$ or similar – i.e. one wind turbine for every $50\text{x}D^2$ m^2 of land.

The following factors will enter into the decision on wind farm layout :

- Investment – WTG's, construction, roads, power cables and communication
- O&M costs
- Land costs
- Annual Energy Production

The analysis made for Zafarana assessed 5 different candidate layouts illustrated in Figure 10 below. Each of the layouts are shown graphically on a plot of the height contours for the site, also indicating the spacing between wind turbines and rows as well as the estimated annual energy production, AEP, and the wind farm array efficiency, γ, assuming that the wind farm is built using one and the same type of wind turbine.

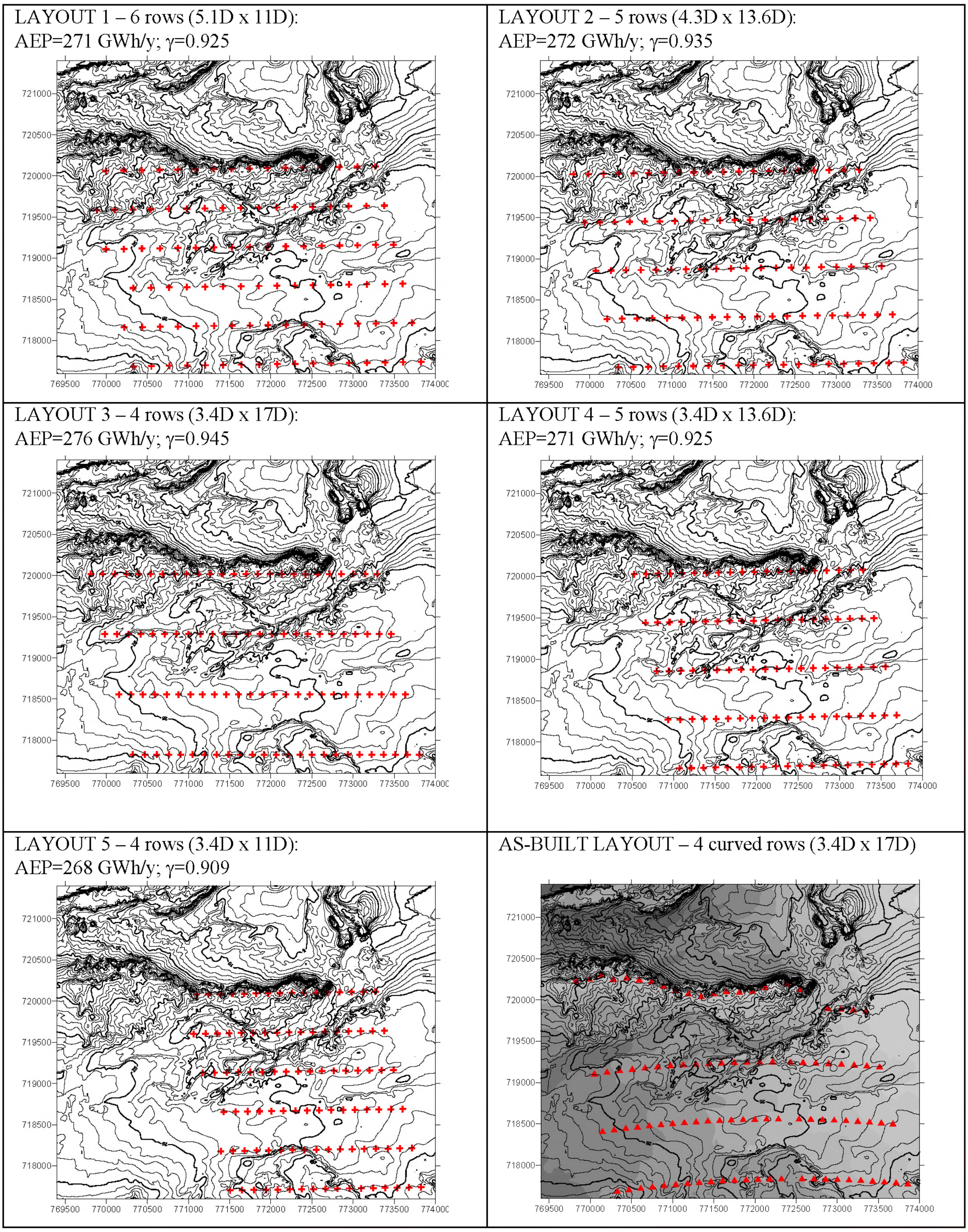


Figure 10. Sensitivity to layout of the 60-MW Zafarana Wind Farm – height contours for the site, spacing between wind turbines and rows (layouts), estimated annual energy production (AEP) and the wind farm array efficiency (γ).

4.5 Wind Power Production Estimation, Verification and Uncertainties

Estimation of the wind resource ranges from overall estimates of the mean energy content of the wind over a large area – called *regional assessment* – to the prediction of the average yearly energy production of a specific wind turbine or wind farm at a specific location – called *siting*. The information necessary for siting generally needs to be much more detailed than in the case of regional assessment. However, both applications make use of the general concepts of topography analysis and regional wind climatologies.

Meso-scale effects – i.e. the forcing of the wind flow by e.g. mountains and wide valleys – are very pronounced in the Gulf of Suez. Consequently, the regional or geostrophic wind climate may change rapidly over short distances. The wind atlas methodology cannot adequately resolve these variations because of the limited number of stations in the Gulf. The KAMM/WAsP methodology is introduced in order to alleviate the shortcomings of the wind atlas methodology.

The KAMM meso-scale model can be used for regional assessment, i.e. to estimate the overall variation of the wind resource over the Gulf of Suez – based on the long-term climatology of the atmosphere.

The WAsP micro-scale model can be used for siting purposes, i.e. to predict the annual energy production of single wind turbines and wind farms at specific locations – based on wind measurements at nearby met. stations.

The KAMM/WAsP methodology is used for wind climate and power production estimations at locations far from existing met. stations, i.e. the predictions of annual energy production are adjusted to take into account the variation of the wind climate on the meso-scale. Such wind power production estimates are less reliable than those obtained from on-site wind measurements.

4.5.1 WAsP wind resource assessment

In general, accurate predictions of wind climate and annual energy production based on observed wind climates require that the predictor (met. station) and the predicted site (turbine) should be as similar as possible with respect to:

- Topographical setting
  - ruggedness (RIX index)
  - elevation and exposure
  - distance to significant roughness changes (coastline)
  - background roughness lengths
- Climatic conditions
  - regional wind climate (synoptic and meso-scale)
  - general forcing effects
  - atmospheric stability

This is often referred to as the *similarity principle*.

With respect to WAsP, accurate predictions using the WAsP BZ-flow model – and indeed most other wind resource assessment and siting models – may be obtained (Bowen and Mortensen, 1996) provided:

- the meteorological station and wind turbine site are subject to the same overall weather regime, i.e. that meso-scale effects are not significant,
- the prevailing weather conditions are close to being neutrally stable, and
- the surrounding terrain (of both sites) is sufficiently gentle and smooth to ensure mostly attached flows.

The first two requirements are particularly important in the Gulf of Suez; the latter has a significant impact on the accuracy of WAsP predictions in complex terrain.

As an example, consider the met. stations in the Zafarana area, see Figure 11.

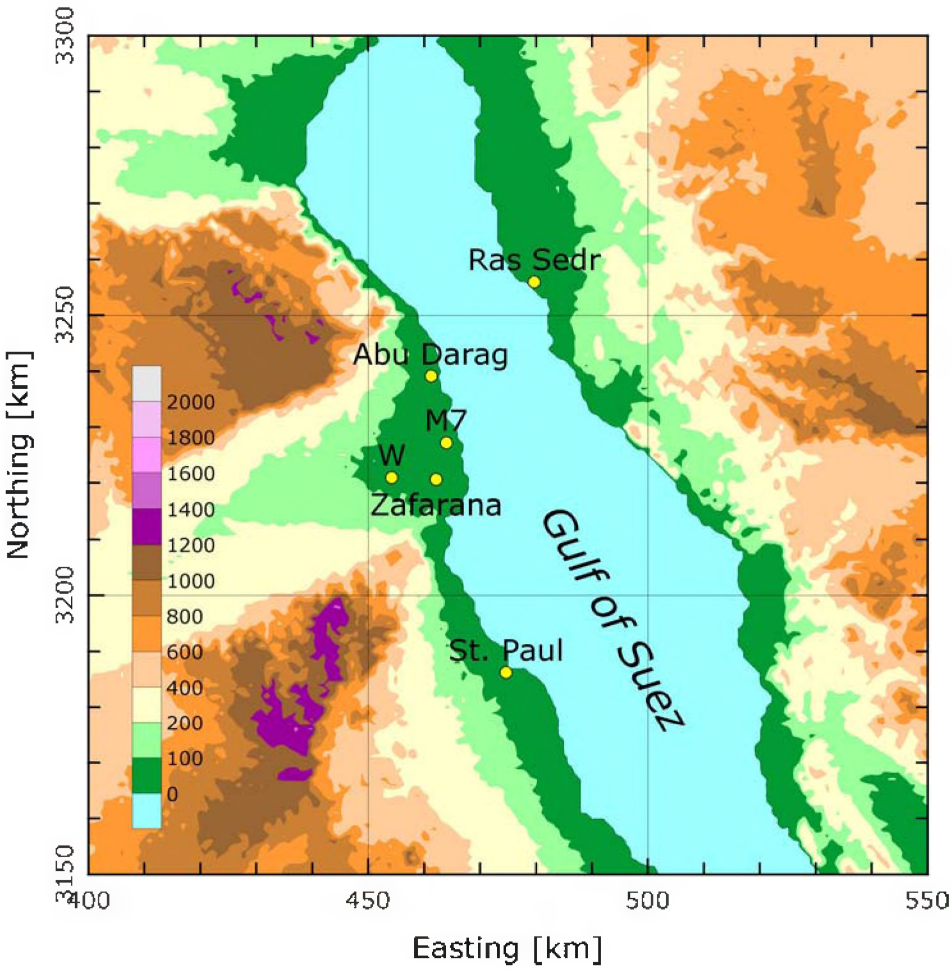


Figure 11. Met. stations in the northern part of the Gulf of Suez.

There are four met. stations close to Zafarana: Abu Darag, Mast 7, Zafarana and Zafarana West. They are situated in the very similar topographical settings close to the sites, but the distances to the coast line are different. Furthermore, the flow in this area is highly influenced by meso-scale effects originating in the large-scale topography.

Table 5 shows cross-predictions between the four met. stations in the Zafarana area using the WAsP model. Each station is used to predict the wind climates at the other three stations as well as the wind climate at the station itself.

Table 5. Comparison of predictions from four stations in the Zafarana area. The rows contain predicted the mean wind speed and power density for each station; each column corresponds to a predicting station. The right-most column contains the wind climates as observed at the stations. The diagonal line of bold face figures thus indicates the stations predicting themselves.

Station	Units	Abu Darag	Zafarana Mast 7	Zafarana	Zafarana West	Measured means
Abu Darag	[ms^{-1}]	**8.83**	8.95	9.40	7.94	8.82
	[Wm^{-2}]	**584**	623	750	497	586
Z. Mast 7	[ms^{-1}]	9.15	**9.14**	9.58	8.03	9.21
	[Wm^{-2}]	654	**657**	785	507	664
Zafarana	[ms^{-1}]	8.60	8.47	**8.91**	7.51	8.97
	[Wm^{-2}]	554	526	**626**	412	630
Z. West	[ms^{-1}]	8.66	8.56	9.02	**7.56**	7.48
	[Wm^{-2}]	561	546	654	**424**	429

The four stations lie within an area which is only about 10 km E-W and 19 km N-S. Abu Darag and Mast 7 are both situated close to the coastline, about 12 km apart, in very similar topographical settings. These two stations predict each other quite well.

Zafarana and Zafarana West are situated about 5 km and 14 km from the coastline, respectively, in the middle of a wide valley oriented WSW-ENE, see Figure 11. Here, the overall wind climate is different and changing due to mesoscale effects and the stations cannot be used to accurately predict each other. Zafarana overestimates the wind climate found at the other stations and Zafarana West significantly underestimates the same stations. Production estimations of the Zafarana wind farms, which are located just W of Mast 7, should therefore be done using the long-term data from Abu Darag rather than the long-term data from Zafarana – even though the distance to the Zafarana station is much shorter.

The variation of the wind climate in this area is shown in more detail in Figure 12. Even though the KAMM model results are probably less reliable than results obtained by measurements and micro-scale modeling, the map indicates clearly that the mean wind climate changes significantly close to NREA's wind farm sites. On-site measurements – at several positions for one or more years – are therefore required to obtain characteristic wind resource estimates over any sizeable wind farm site in this area. While such estimates may be reliable with respect to the present wind climate, it has to be taken into account that even small changes in the overall flow patterns in the Gulf of Suez – caused by climatic variability or even climatic change – may add considerably to the uncertainty of a given project.

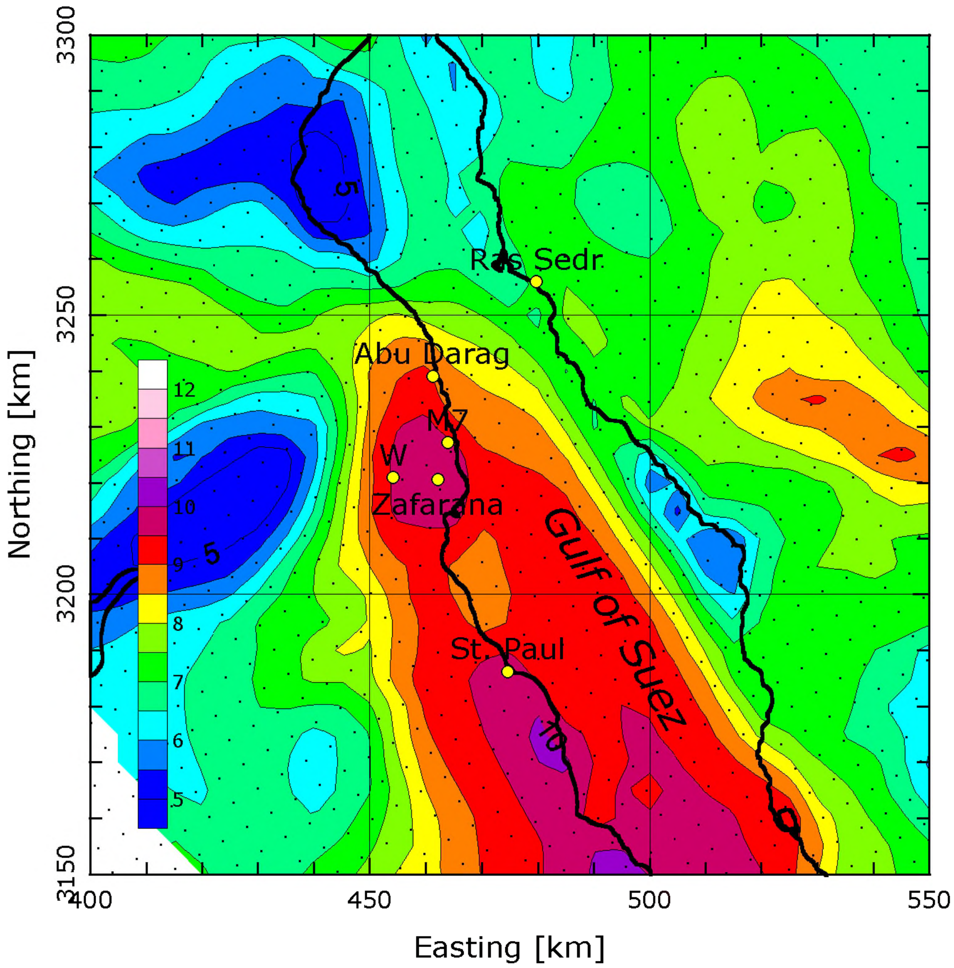


Figure 12. Map of KAMM-modelled mean wind speeds in the northern part of the Gulf of Suez. Wind speed is given in m/s.

4.5.2 Uncertainties in wind resource assessment and production estimation

Wind resource assessment is associated with numerous types of uncertainties many of which have been discussed in the literature – see e.g. "Accuracy of Estimation of Energy Production from Wind Power Plants", Wind Engineering, Vol 16 No. 5 1992, Ref [30].

<u>Uncertainties related to long-term and regional variations in wind climate</u>

- *Climatic variability of the wind climate*
- *Longer-term variations and climatic change*

Any wind resource assessment exercise in the Gulf of Suez should attempt to make the necessary corrections for the measurement period relative to the long-term average wind climate. This may be done using data from wind atlas measurement stations, which can be found in the **database** of Wind Atlas for the Gulf of Suez 1991-2001, Ref [1]. Some of these stations have recorded the wind climate since 1991 and will therefore provide the necessary information.

An example is shown in Figure 13, where the database has been used to estimate the yearly production of a wind turbine for the period 1991-2001. The yearly production varies by about ±12% from the long-term average during the 11-year period.

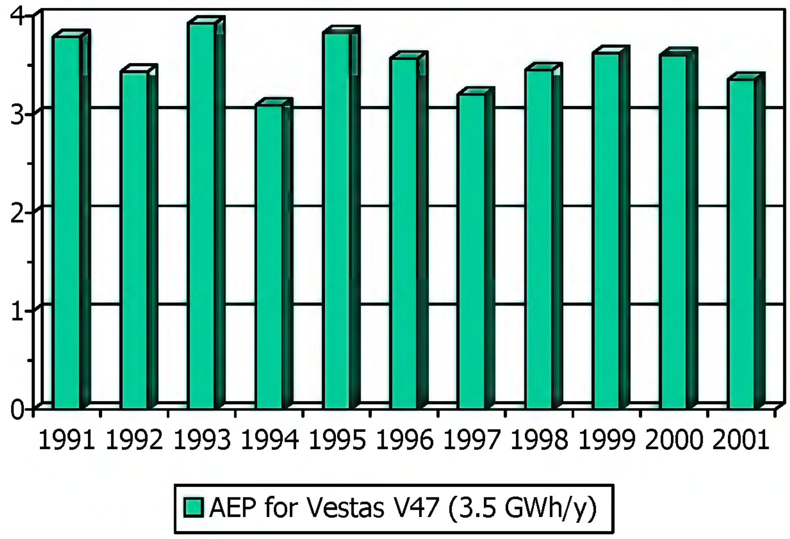


Figure 13. Year-to-year variation of the estimated production from a Vestas V47 wind turbine close to Abu Darag. The average production for the 11-year period is 3.5 GWh/y.

Longer-term wind data series are available from the NCEP/NCAR reanalysis data set, but it is not yet clear whether these data can be used to estimate the long-term variations close to the ground in the Gulf of Suez. Likewise, little is also known about climatic change in this region and the impact this may have on the power output from wind farms.

- *Large-scale effects on wind climate by large wind farms*

The uncertainty due to large-scale effects on wind climate by large wind farms is very difficult to quantify and it is p.t. a subject for research in particular related to off-shore applications. Results of this research will be relevant for Gulf of Suez applications as well. The papers Ref [31] and [32] on large-scale wind farm effects provide recommendations with respect to handling such uncertainties.

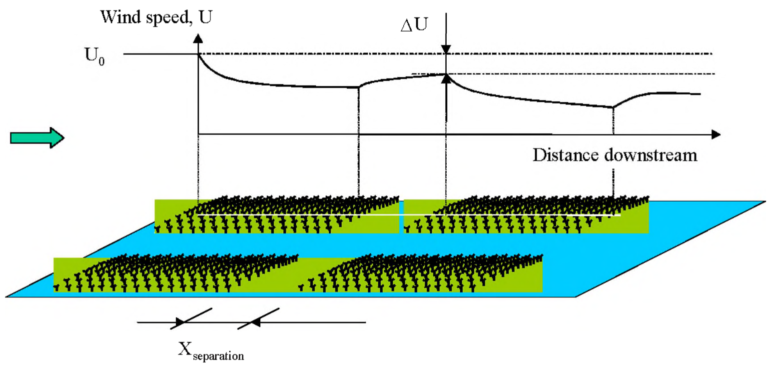


Figure 14 Graphical sketch of large-scale wake effects and impact on general wind climate

It becomes necessary at large wind farms to do more than to run WAsP/PARK in its present version 8. The basic idea at present is at least to associate an up-wind wind farm (outside the distance to which wake models have an impact on results) with an increased terrain surface roughness in both meso-scale and micro-scale models – KAMM and WasP. Such roughness estimation recommendations may be found in "Modelization of a large wind farm considering the modification of the atmospheric boundary layer", Ref [32]. The database from Wind Atlas for the Gulf of Suez 1991-2001, Ref [1], may be used to verify such estimates.

- *Gradients in wind climate within the Gulf of Suez*

It can be seen from Figure 12, which is a zoom-in on the Zafarana region from the KAMM modeling results presented in the Wind Atlas for the Gulf of Suez, that the gradients in the wind climate around Zafarana are significant. This is also true for the southern part of the Gulf of Suez.

For sites with a limited spatial extent, and where two or more measurement masts exist, it is possible to interpolate between these stations in order to get a reliable estimate of the AEP for a wind turbine or wind farm. A technique for interpolation between wind atlases has been suggested by "A Method for Spatial Interpolation of Wind Climates'', Ref [33]. This method may be useful both in site selection studies as well as in the more detailed studies for optimization of the wind farm layout.

For sites with a large spatial extent, or for sites far apart, it is not possible to use simple interpolation schemes. In such cases, one must 'interpolate' using a meso-scale model with a fine resolution in the grid. The KAMM results presented in Ref. [1] may be used for a qualitative analysis all over the Gulf of Suez; however, these results are not reliable for obtaining accurate resource estimates for siting and layout optimization. Adaptation, test and development of such meso-scale models must be carried out in order to increase the accuracy of the model results.

<u>Uncertainties related to flow modelling</u>

- *Uncertainties associated with WAsP flow modeling*
- *Uncertainties associated with KAMM flow modeling*

The uncertainties associated with WAsP flow modeling in general have been identified and described elsewhere – see Refs [1], [10], [12]- including the present report and the Wind Atlas for the Gulf of Suez. Most of these uncertainties are well known and also apply to the Gulf of Suez. These uncertainties are not particularly pronounced in the Gulf of Suez and their sum will generally amount to less than 10% – if adhering to good engineering practices. Even development of new and improved micro-scale models is not likely to improve the reliability of WasP-based resource estimates dramatically.

One points that deserves more attention in the future, though, is the extrapolation of wind climate estimates to larger heights (50-150 m above ground level) from measurements made at heights of 10-50 m a.g.l. Furthermore, other important extensions to the wind atlas methodology in the near future will be

- *Model parameter studies and adaptation of models to local conditions*

- *Sensitivity analyses, site calibration and verification of modelling results*

These extensions of the wind atlas methodology will be highly applicable to the Gulf of Suez. However, the largest uncertainty is related to the very pronounced meso-scale effects in the Gulf of Suez.

The uncertainties associated with KAMM flow modeling in general have been described in the literature. The numerical wind atlas methodology – known here as the WasP/KAMM method - is described in detail by Frank et al. Ref [7].

Uncertainties related to wind measurements

Wind measurements and monitoring programmes for wind resource assessment may in this context be divided in two types

type 1 station: the wind atlas measurement stations as e.g. the stations used for establishing the database of Wind Atlas for the Gulf of Suez 1991-2001, Ref [1]

type 2 station: on-site measurements for calibration of flow model and site characterisation at a given wind farm site area, at which measurements are made and modeling comparisons are made with predictions made based on data from the database, Ref [1]. Further regarding method to do calibration of flow model and site characterisation see Ref [29].

Recommendations on quality and accuracy requirements to limit uncertainties from meteorological stations and measurement equipment are given below - valid for both type 1 stations and type 2 stations if no other indications are made:

- accuracies of equipment according to IEC 61400-12 Annex D for Wind turbine power performance testing – quality and calibration documented by traceable calibration
- track record of anemometers documenting service life of at least two years more than the planned measurement period
- masts to be designed according to applicable national and/or international standards
- mast (measurement) height
  - *type 1 station:* for general resource assessment in the flat homogeneous coastal terrain: 24.5 m as used for Wind Atlas for the Gulf of Suez 1991-2001, Ref [1]
  - *type 2 station:* for on-site measurements for calibration of flow model and site characterisation: 47.5 m as used at Zafarana Wind Farm – see Ref [29]
- wind speed measuring in at least two levels: 10 m agl on boom perpendicular to prevailing wind direction plus a topmounted anemometer
- automatic data recording of
  - 10 minutes averages of wind speed in two heights (based on 0.5-1 Hz sampling),
  - wind speed standard deviation at topanemometer each 10-min period (based on 0.5-1 Hz sampling),
  - wind speed gust at topanemometer each 10-min period (based on 0.5-1 Hz sampling),
  - wind direction (on boom 2 m below topanemometer),
  - barometric air pressure (only type 1 stations),
  - air temperature (only type 2 stations)

- data processing via satellite communication or mobile phone system may be recommendable in order to enable remote monitoring and collection of recorded data from the data logging system

<u>Uncertainties related to topographic maps</u>

Topographic maps – including height contour and roughness (land use) maps – should be of the series used for the Wind Atlas for the Gulf of Suez, Ref [1]. The sensitivity of wind resource assessment to the accuracy and detail of the topographical input data were demonstrated in Section 5.2 above.

<u>Uncertainties in wind turbine power performance</u>

Uncertainties in wind turbine power performance may be divided in two

a) those related to the wind turbine power curve, i.e. the power output as a function of the 10 minutes average wind speed at hubheight, and
b) those related to the wind turbines technical availability.

Re a) Wind turbines should be supplied with a warranted power curve, which may be checked doing power performance verification in accordance with IEC 61400 – 12. The uncertainty of the power performance verification will be quantified through the IEC performance verification methodology. However, some major sources of uncertainty remain, among others:

- the power curve verification will be performed only for a few wind turbines in a wind farm, since an open fetch to northerly winds (prevailing wind directions) is necessary according to IEC 61400-12,
- dust on blades (or other degradation or sandblasting) may change aerodynamic performance - as documented by Ref [37] leading to a reduction in annual energy production up to 7% at Zafarana for the 300 kW wind turbine tested by Ref [37]
- fine tuning of the wind turbines (especially the set blade pitch angles) may vary from wind turbine to wind turbine
- wind turbine power performance may vary during the 20 years performance life
- wind turbine power performance relative to the 10 minutes average hubheight wind speed will vary as a function of turbulence intensity and vertical wind speed profile
- appropriate corrections for the variations in air density (temperature and pressure) should be made according to IEC 61400-12

Re b) Wind turbine technical availability may be the responsibility of the supplier for the warranted number of years during which period contractual penalties may compensate the losses due to lower availability than warranted. For the remaining life of the wind turbines, availability very much depends on operation & maintenance planning and the maintenance quality, assuming that the quality of the wind turbine is in accordance with specifications. The uncertainties in technical availability of wind turbines should be expected to increase with age of the wind turbine due to the relative youth of the wind turbine technology.

<u>Uncertainties in wind farm array efficiency</u>

Some limitations of the wake model implemented in the WasP PC-software package - Section 4.3 - should be mentioned:

The distance between neighbouring turbines in the farm should be larger than about four diameters.

For very large arrays (the model can handle several 100's of turbines) there might be a larger reduction in power production than computed, due to the influence of the turbines on the general roughness description for the site.

The model is not able to properly handle speed-up and slow-down effects, which may be important for wind farms in complex and mountainous terrain. The wakes are supposed to follow the terrain surface of the landscape.

It should be considered as well that wind turbine power output relative to the 10 minutes average hubheight wind speed will vary as a function of turbulence intensity and vertical wind speed profile, and that appropriate corrections for the variations in air density (temperature and pressure) should be made according to IEC 61400-12.

4.5.3 Wind climate and power production verification

Wind climate and power production estimates may be verified by erecting auxiliary meteorological masts where predictions can be compared to observations. Such a large-scale verification experiment is being conducted at the NREA/Danida wind farm site close to Zafarana, Ref. [29]. Here, nine masts have been erected in order to cover the entire wind farm site, see Figure 15. The masts are 47.5 m high and represent hub-height wind conditions for the 600-kW wind turbine which has been employed for the wind farms so far.

Even within this fairly small and homogeneous site, the estimated production vary by more than 20%, from 0.92 to 1.13 times the mean value over the site, respectively. The accuracy of the resource map has been verified by wind measurements at the nine positions (M1-M9) indicated in the map, Ref. [29].

The terrain descriptions were detailed and verified, Ref. [29] by

- modification of the terrain surface roughness descriptions
- inclusion of a detailed elevation map of the site (approx. 3.5 x 5 km^2)

The terrain surface roughness descriptions were modified based on

- scrutiny of stereoscopic aerial photographs
- a detailed site survey (in the mine-swept areas!)
- "measured" z_0-values at the site, i.e. z_0-values found from the vertical profile of wind speeds measured at heights of 10 m, 24.5 m and 47.5 m a.g.l. at M7.

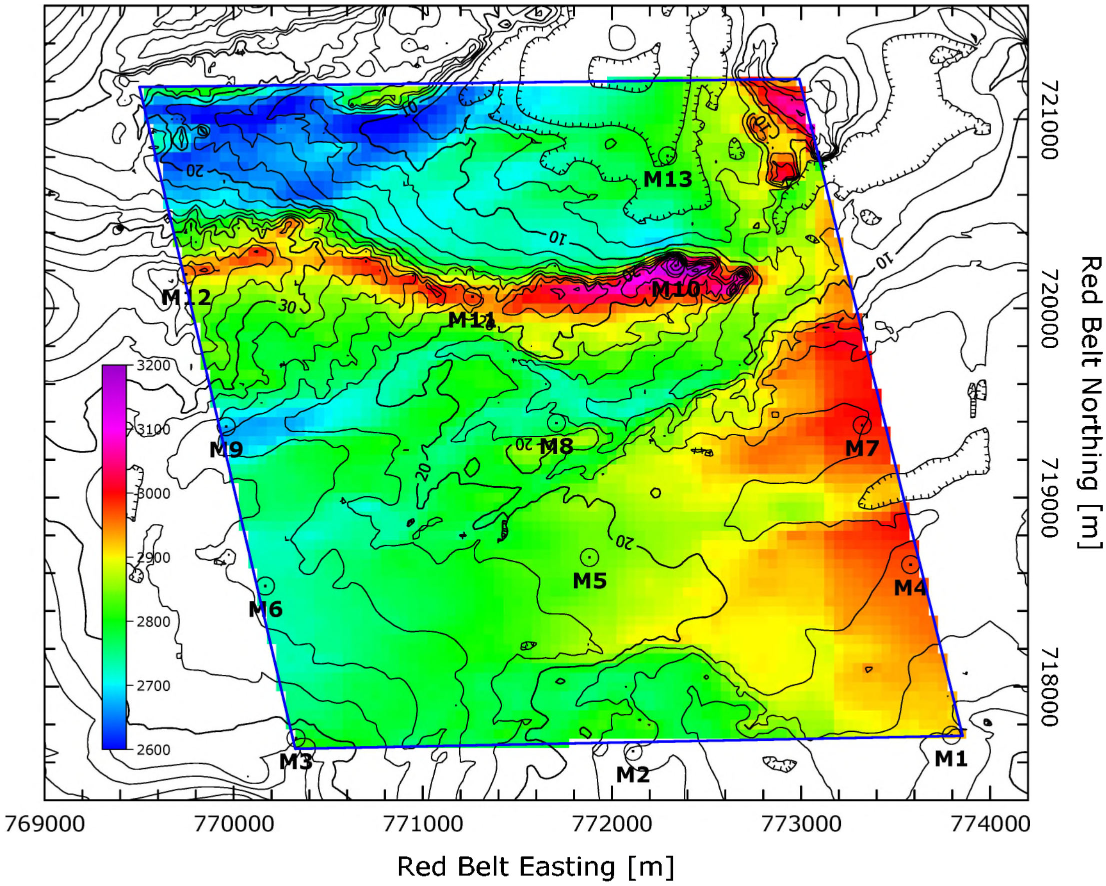


Figure 15. Estimated Annual Energy Production [MWh] for a 600-kW wind turbine at the NREA/Danida wind farm site close to Zafarana. Hub height is 45 m a.g.l. and the power production was calculated in a regular grid with a grid point spacing of 50 m. Height contour interval is 2 m. The position of several meteorological masts (M1-M13) are indicated as well.

Comparisons of measurements and predictions show accurate predictions of the wind speeds at the wind farm site by the Abu Darag mast with resulting average prediction errors of less than 1%. Conversely, the Zafarana mast significantly over-predicts the wind speeds at the wind farm site. The average over-prediction by the Zafarana mast is 7.5%.

4.6 Environmental Impact Assessment

Wind turbines produce energy without pollution, eventually leading to a reduction in the emission of carbon dioxide, nitrogen oxide and sulphur dioxide. The use of wind energy may therefore contribute to reduce global climate change, acid rain and other serious environmental problems.

Although the environmental impact of wind energy obviously is lower than that of conventional energy sources, there are some potentially negative effects on the environment, especially when it comes to establishing wind energy schemes of several hundred turbines. Over the years the main environmental concern when constructing wind turbine parks has been

Modern wind turbines are extremely durable and the danger of parts of a turbine such as a wing part hitting buildings or persons must be regarded as remote.

Furthermore, wind turbines have several braking systems to stop the wings in case of extremely strong winds or a malfunction. As modern wind turbine are also very quiet it normally possesses little problems to build wind turbines close to human settlements. The visual effects of wind turbine may, however, create some controversy, as some people believe they are having a severe negative visual impact of the landscape while others find them beautiful!

The impact on plants and animals can be divided into three types:

Deterioration and fragmentation of habitats (flora and fauna in general)
Disturbance (birds and mammals)
Risk of collisions (birds)

The actual impact on flora and fauna depends on:

Occurrence of sensitive species of plants and/or animals
Number, placement and proportions of the wind turbines
Infra structure of the project (i.e. presence of access roads, transmission lines etc.)

Since the western bank of the Gulf of Suez has a hyper-arid environment and most of the coastal plains and the Red Sea Mountains are almost completely without vegetation the resident natural flora and fauna is extremely sparse. Environmental Impact Assessments in these areas will therefore mainly deal with the potential treats of migrating birds colliding with wind turbines and associated power lines.

4.7 International standards - IEC

The International Electrotechnical Commission (IEC) has undertaken to develop international standards for wind power. A list of publications as well as ongoing standardisation is include in Annex B.

A standard often referred to is the IEC61400-12 Power Performance Verification, specifying wind and performance measurement requirements.

The General standard for wind turbine design and safety is IEC61400-1 ed. 2.

IEC61400-1, main contents:

- Structural design
  – Design methodology
  – Loads – stochastic, deterministic, extremes, calculations
  – Design situations and load cases
- Design methods
- Safety classes
- Quality assurance
- Wind turbine markings
- External conditions - ”Design climate” in wind farms (Turbulence and wind speed)
- Control and protection system
- Mechanical systems
- Electrical system

- Compatibility for site-specific conditions
- Assembly, installation and erection
- Commissioning, operation and maintenance

Central in IEC61400-1 is the specification of characteristics of wind turbine classes:

Table 1 - Basic parameters for wind turbine classes

Wind Turbine Class	I	II	III	S
V_{ref} (m/s)	50	42,5	37.5	Values
A I_{ref} (-)	0,16			Specified
B I_{ref} (-)	0,14			by the
C I_{ref} (-)	0,12			Designer

It should be noted that

$$V_{ave} = 0.2V_{ref}$$

Hubheight annual average wind speeds, V_{ave} may at Zafarana and El Zayt reach 11 – 13 m/s, respectively, which means that IEC Class S wind turbines should be applied. Such wind turbines may not be standard products from the manufacturer, and a site-specific certification will be strongly recommendable.

Finally, please note the IEC WT 01 (2001-04) IEC System for Conformity Testing and Certification of Wind Turbines - Rules and procedures.

5 Case at the Gulf of El-Zayt

In order to illustrate in more detail the wind farm planning process and some of the other procedures outlined in this report, we present below a case study from the southern part of the Gulf of Suez, close to the small Gulf of El-Zayt.

5.1 Background information

The map in Figure 16 shows the terrain elevation and other topographic features of the southern part of the Gulf of Suez, as well as the positions of the meteorological stations in the region. The study area is centered around the four met. stations close to the center of the map.

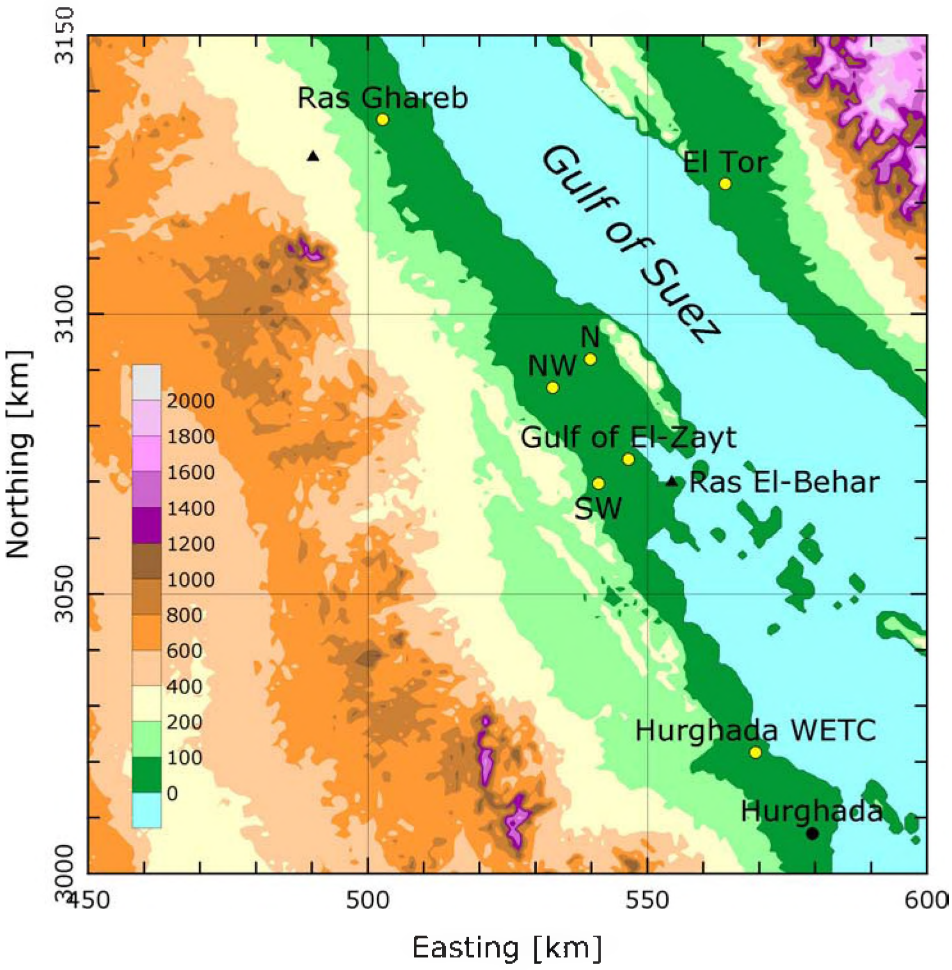


Figure 16. Met. stations in the southern part of the Gulf of Suez.

Figure 17 shows the overall mean wind climate in the same region, as modeled by the KAMM model. The KAMM model is not able to accurately model the mean wind speeds observed at the four met. stations; nevertheless, the results indicate that the wind resource changes significantly with horizontal distance in this region.

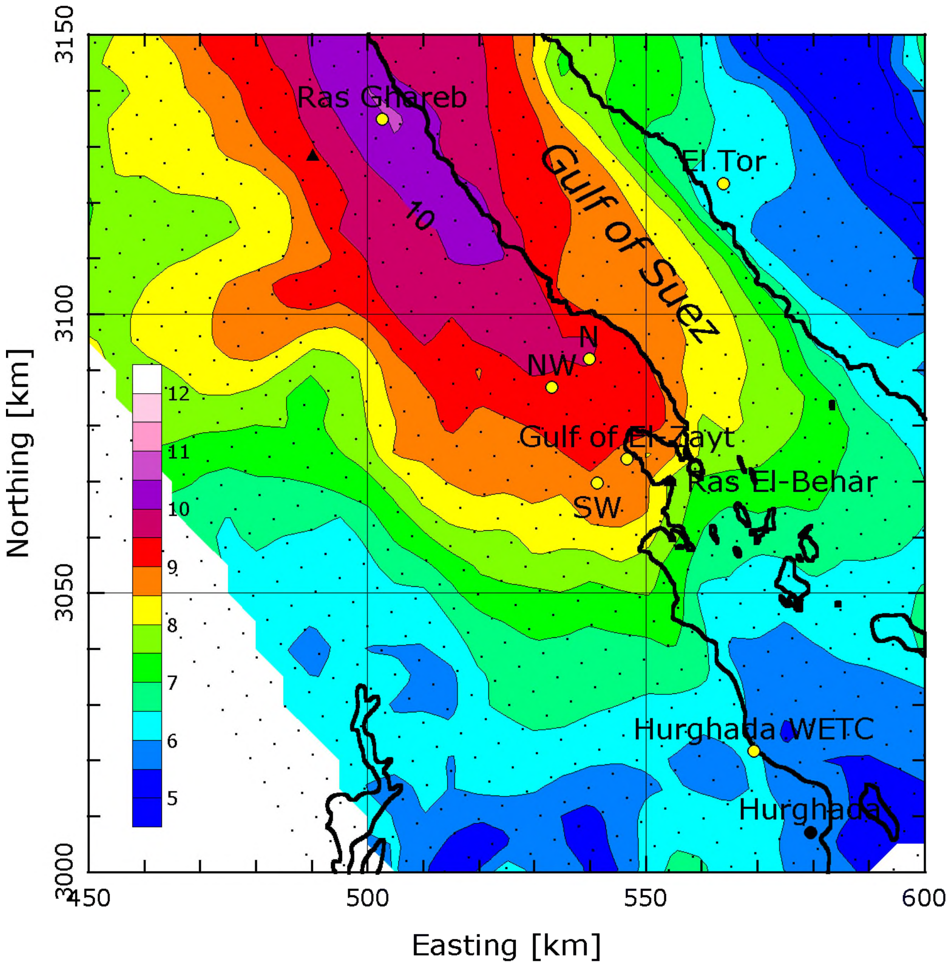


Figure 17. Map of the KAMM-modelled mean wind speeds in the southern part of the Gulf of Suez.

The study area is thus naturally bounded by the mountain ranges to the SW and by the sea the NE. To the S, the study area is naturally bounded by the significant decrease in the wind resource that takes place between the two southernmost met. stations and Hurghada. To the NW, the terrain is a coastal plain and the wind resource is consistently high; the study area is therefore not bounded by natural features in this direction.

5.1.1 Topography and land use

Figure 18 shows a detailed map of the study area. This map was obtained by digitization of standard topographical maps at a scale of 1:50,000, and is also the map used for the flow modeling and other calculations in the case study below.

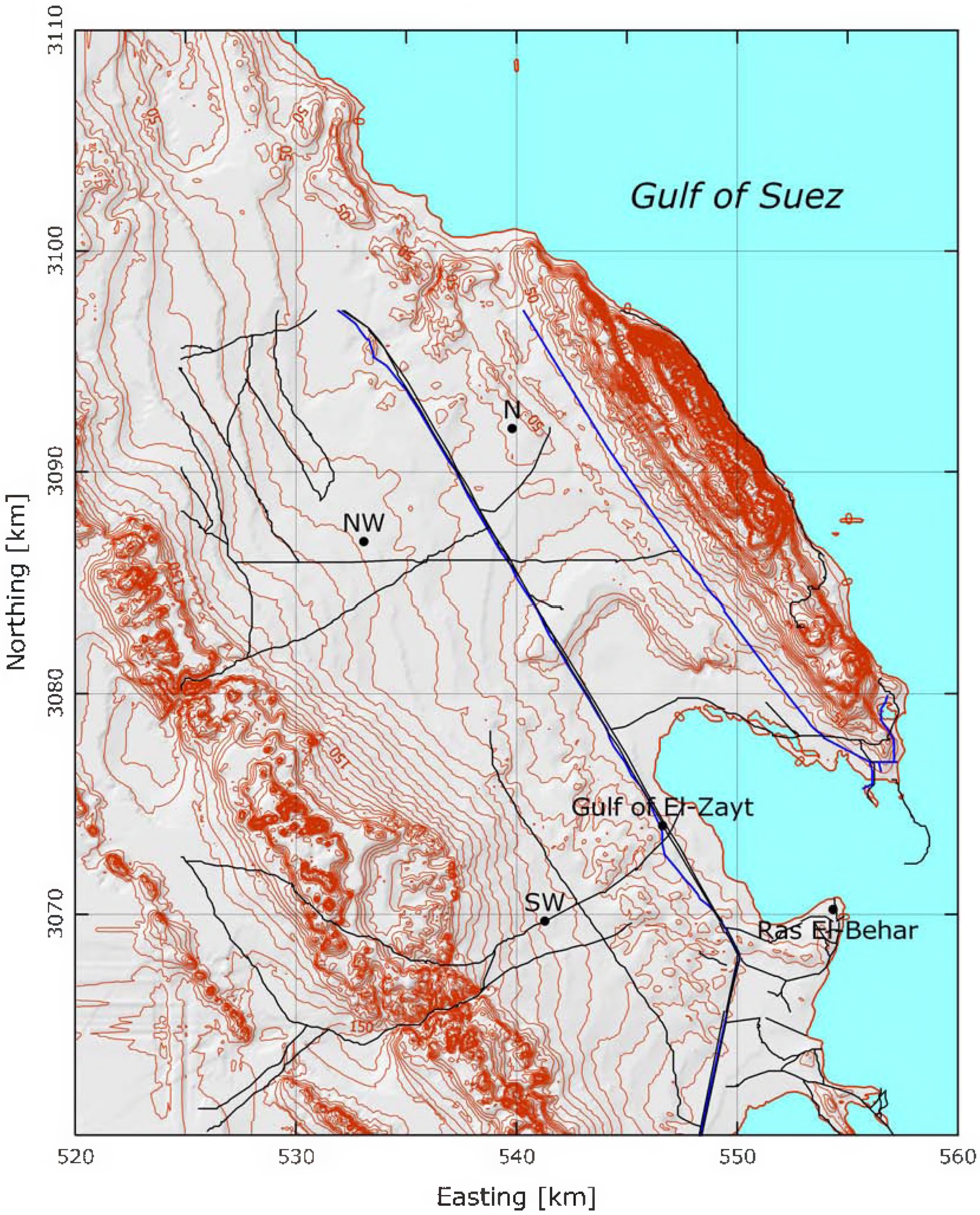


Figure 18. The area around Gulf of El-Zayt used for the case study. The height contour interval is 10 m and the black dots mark the positions of five met. stations in the area – Ras El-Behar is a historical station and it is not used for the calculations. Roads are shown in black, pipelines in blue.

5.1.2 Wind resources

Figure 19 shows the details of the wind climate as modeled by the KAMM model. The mean wind speeds represent 2.5 by 2.5 km^2 squares; these values were obtained by interpolation of the basic 5-km data (i.e. mean wind speeds obtained with KAMM using an elevation grid with 5 km between the points).

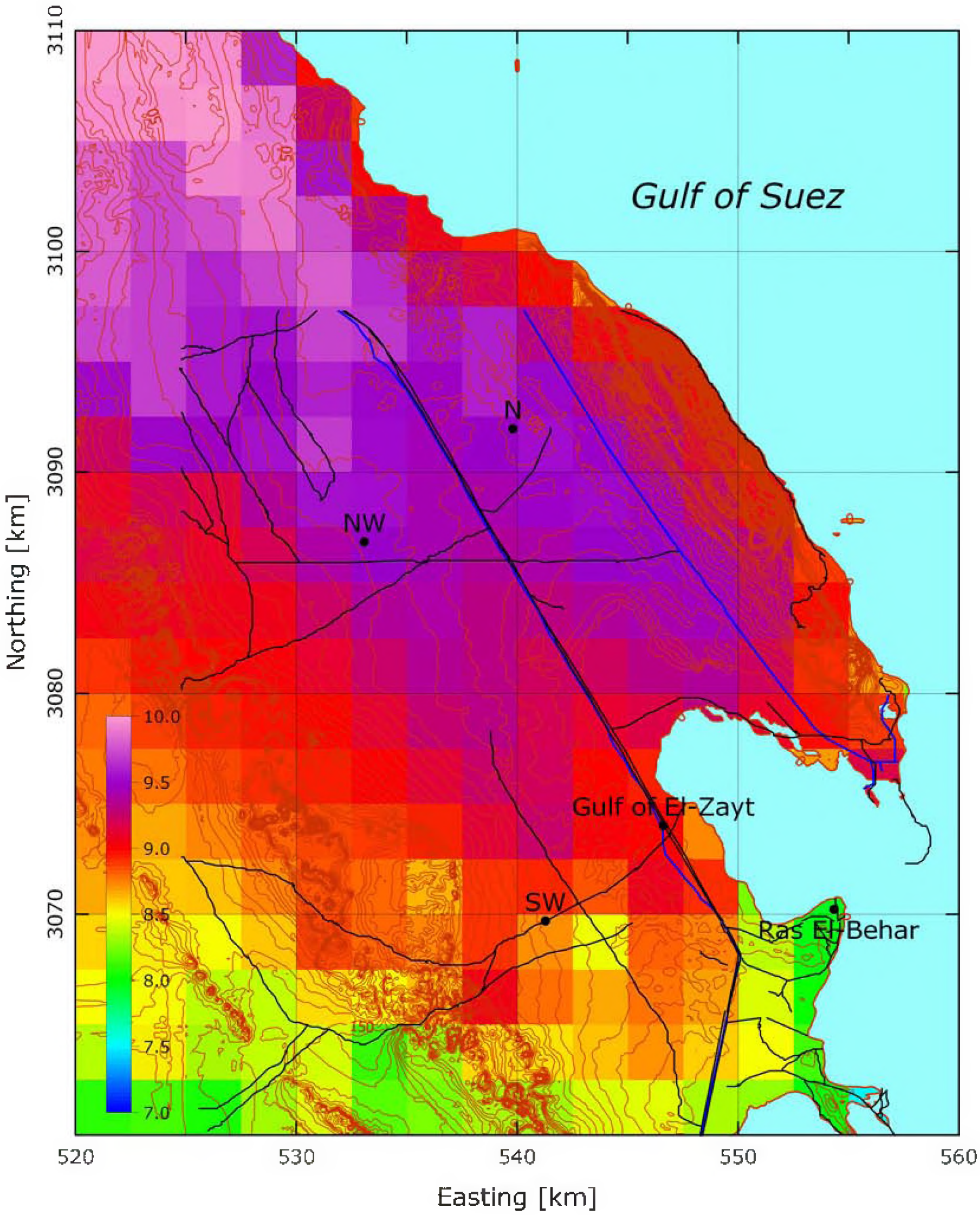


Figure 19. Map of the KAMM-modeled mean wind speeds over the case study site. The grid size is 2.5 km.

5.1.3 Bird migration

Statistics of bird migration data can be calculated for the same 2.5-km squares. Figure 20 shows the bird migration density for the spring season and Figure 21 the bird migration for the autumn season. Note, that only squares with bird observations have been colored; the absence of color does not mean that there are no birds, only that there is a lack of observations.

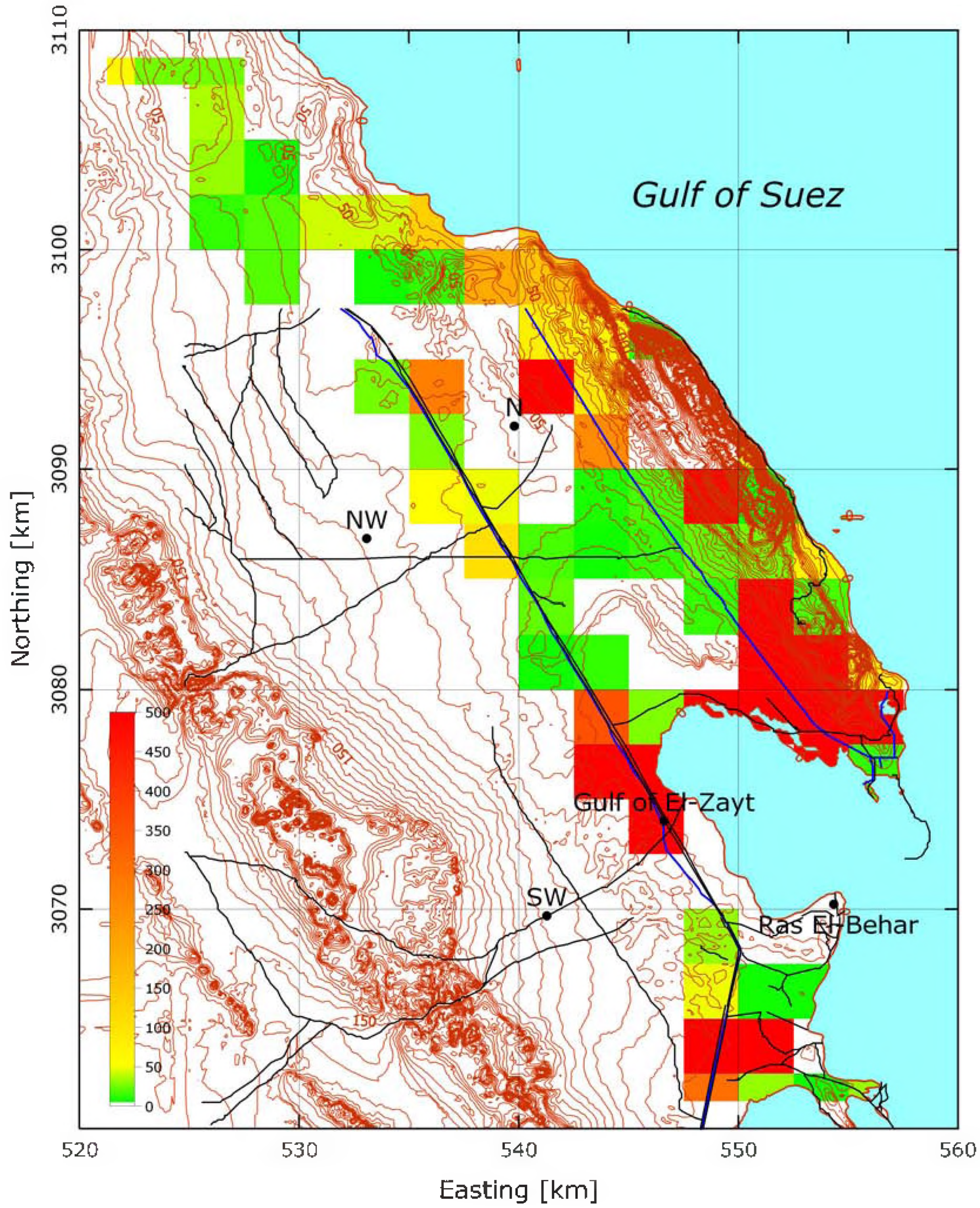


Figure 20. Bird migration at the Gulf of El-Zayt during spring. Note, that only squares with bird observations have been colored; the absence of color does not mean that there are no birds, only that there is a lack of observations.

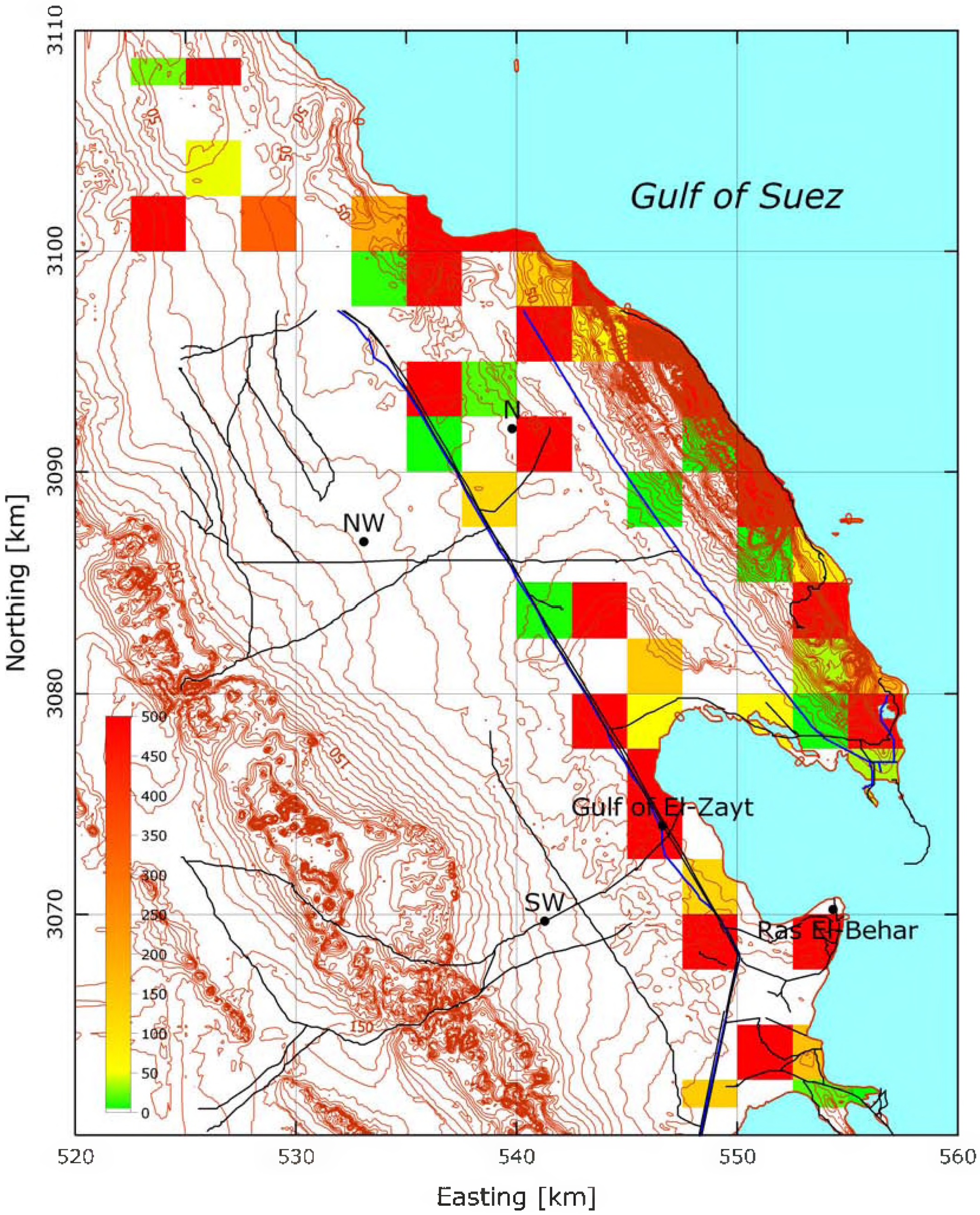


Figure 21. Bird migration at the Gulf of El-Zayt during autumn. Note, that only squares with bird observations have been colored; the absence of color does not mean that there are no birds, only that there is a lack of observations.

5.2 Siting

Based on the topographical and wind resource maps given above, we can now identify which parts of the area in question might be feasible for wind power exploitation and which therefore deserve closer study.

- To the W, the wind farm area is naturally bounded by the mountain ranges. In practice, wind turbines cannot be installed at elevations higher than about 100 a.s.l., because of the proximity of the mountains.

- To the E, the wind farm area is bounded by the main road from Hurghada to Cairo, since the area between this road and the sea has been reserved for other purposes, e.g. resorts, summer residences and other built-up areas.

- To the S, the study area is naturally bounded by the significant decrease in the wind resource that takes place between the two southern-most met. stations and Hurghada.

- To the N, the terrain is a coastal plain and the wind resource is consistently high; the study area is therefore not bounded by natural – or man-made – features in this direction.

The bulk wind farm area determined in this way is shown in Figure 22.

5.2.1 Further considerations and assumptions

Even though all sites within the bulk wind farm area may be more or less feasible for wind power exploitation, different parts of the bulk site have different characteristics. A number of further observations and considerations might be:

- The southernmost part of the area is close to a wind resource gradient (decrease) towards south. Not only would we like to avoid the apparently lower AEP; we would also expect an increased economic risk when establishing wind farms close to a significant gradient in the wind resource. This part of the area also seems to be a 'hot spot' for bird migration.
- The westernmost part of the area has the highest wind resource. This part is close to a gradient in the wind resource as well, but most likely a more 'robust' one, since it is caused by the mountains. The foothills and slopes may in some places enhance the flow; however, very close to the mountains we might expect higher turbulence levels. Even though no direct observations exist, one might speculate whether the density of migrating birds is lower in this area.
- The easternmost part of the area, in the middle of the wide valley, has a favorable wind resource and easy access. Getting closer to the coastline and the mountain of Gebel El-Zayt might increase the density of migrating birds and in some places they may occur at lower altitudes. Human activity on the eastern side of the road is likely to increase the roughness, though this may not be a problem well away from the coastline.
- The central and northernmost part of the site has few of the drawbacks mentioned above, even though increased roughness caused by buildings might be more important here. The bird migration patterns are not known in great detail, but a narrower coastal plain might increase the density of bird migration. For sure, this part of the area has the largest distance to existing power lines and consumers.

All considered, an area near the met. station "NW" seems to be the best initial choice for a wind farm site. A view from this met. station towards 330° – which is the prevailing wind direction – is shown in Figure 23.

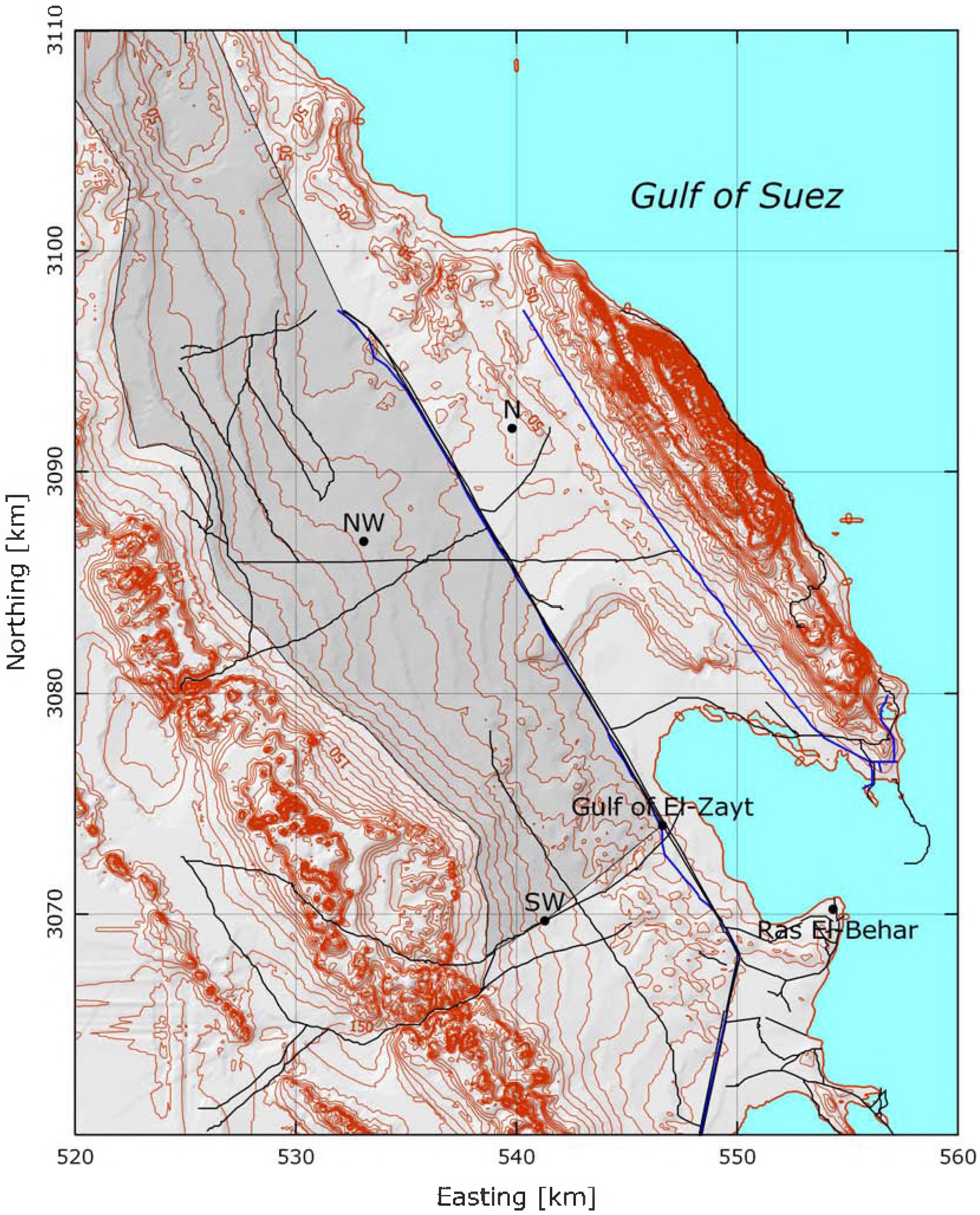


Figure 22. The wind farm bulk site in the Gulf of El-Zayt area. The main road continues to the north, but is not shown here.

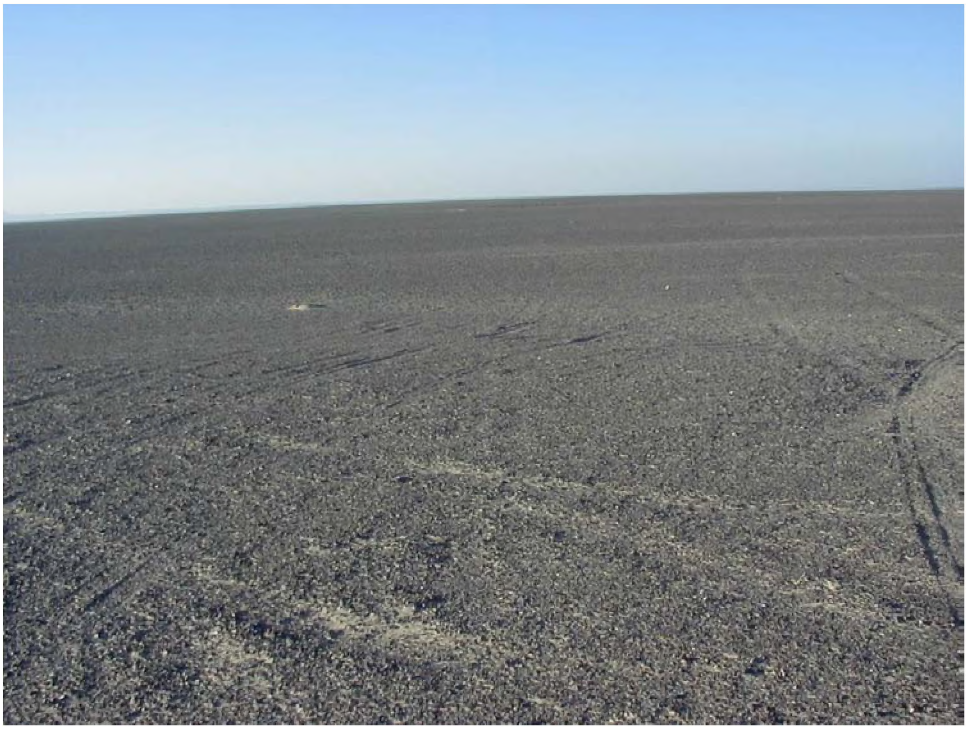


Figure 23. View towards 330° from the met. station "Gulf of El-Zayt NW".

5.2.2 Terrain descriptions

The map used for WAsP flow modeling is shown in Figure 18. The height contour interval is 10 m. This interval is sufficiently small, considering the geometry of the terrain, see Figure 23. By the same token, terrain slope and terrain ruggedness close to the wind farm site are not important for the flow modeling.

The terrain has been divided in two roughness classes for this study: land (desert) and water (sea). The roughness length has been set to 0.003 m; this is probably a bit low for most sites. Using this simple map for both the met. station and the wind farm predictions will then to lead to slightly conservative (lower) estimates for the power production.

There are no sheltering obstacles close to the met. station or wind farm site.

5.3 Sizing

The sizing of the wind farm is not limited by availability of land or variations in the wind climate. For the initial analyses we assume the following (somewhat arbitrary) wind farm specifications:

- Wind farm is 100 MW – about three times the size of Zafarana I
- Wind farm consists of 77 1.3-MW Bonus wind turbines
- The hub height for this wind turbine is 60 m and the rotor diameter is 62 m.
- The rotor plane (disc) thus extends from 29 to 91 m a.g.l.

5.4 Layout

The regional wind climate determined from the observations at "Gulf of El-Zayt NW" is shown in Figure 24. For more than 85% of the time, the wind direction occurs in sectors 11 and 12 (center angles 300° and 330°) and the observed mean wind (vector) direction at the station is 313°.

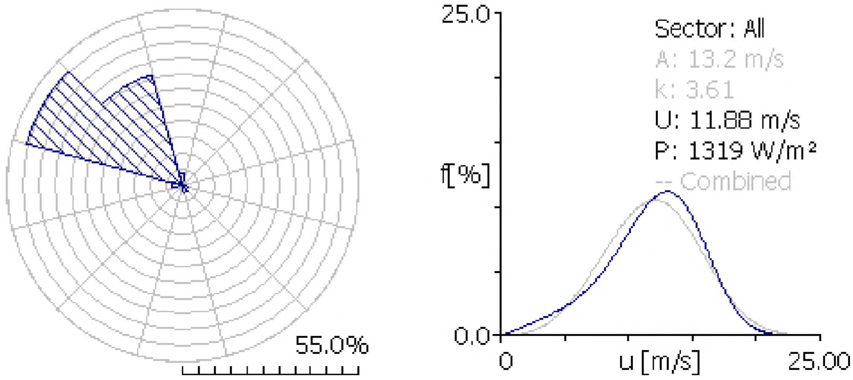


Figure 24. The regional wind climate at "Gulf of El-zayt NW" at 50 m a.g.l. over a uniform, flat surface with a roughness length of 0.003 m. Data covering the period 2000-01.

This strongly preferred wind direction suggests a simple layout of straight or curved rows of turbines, where the rows are perpendicular to the prevailing wind direction. Below, we have chosen four different sample layouts, two linear and two curved. Each farm consists of four rows of 19-20 turbines each; oriented approx. 045°-225°.

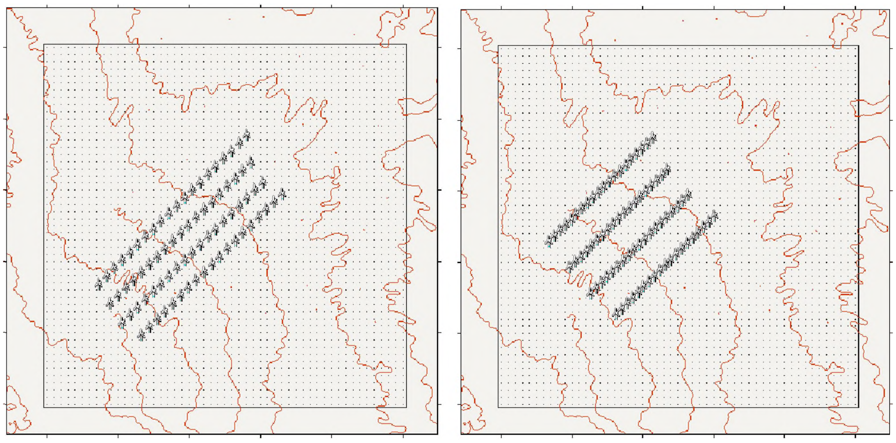


Figure 25. Sample linear wind farm layouts L1 (left) and L2 (right).

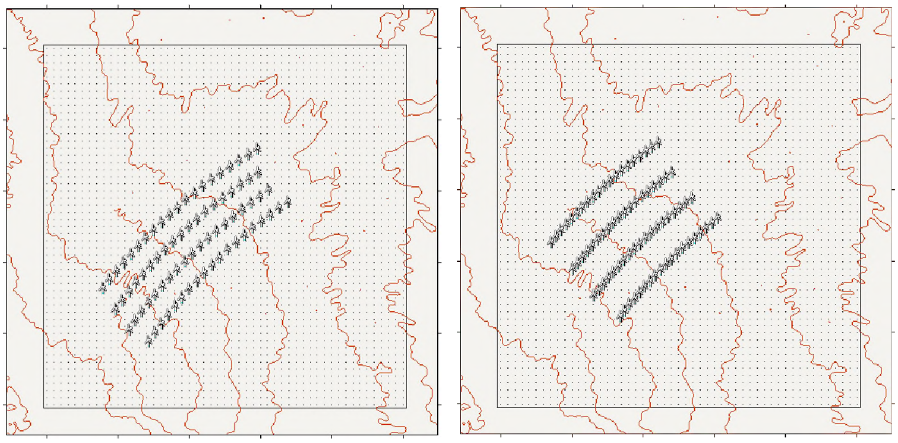


Figure 26. Sample curved wind farm layouts C1 (left) and C2 (right).

In the wind farm layouts L1 and C1, the distance between rows of turbines is about 10 rotor diameters and the distance between turbines in a row about 5 rotor diameters.

In the wind farm layouts L2 and C2, the distance between rows of turbines is about 15 rotor diameters and the distance between turbines in a row about 3.5 rotor diameters.

Other farms with a similar layout could be established anywhere in the area.

5.4.1 Micro-siting

Micro-siting of the wind turbines in this area is particularly simple due to the lack of terrain features that would influence the wind resource significantly. As an example, wind farm C1 is shown in a wind speed map of the area in Figure 28. The mean wind speed varies from about 12.22 to about 12.36 m/s over the wind turbine positions. The corresponding variation in net AEP is from 8.3 to 8.7 GWh.

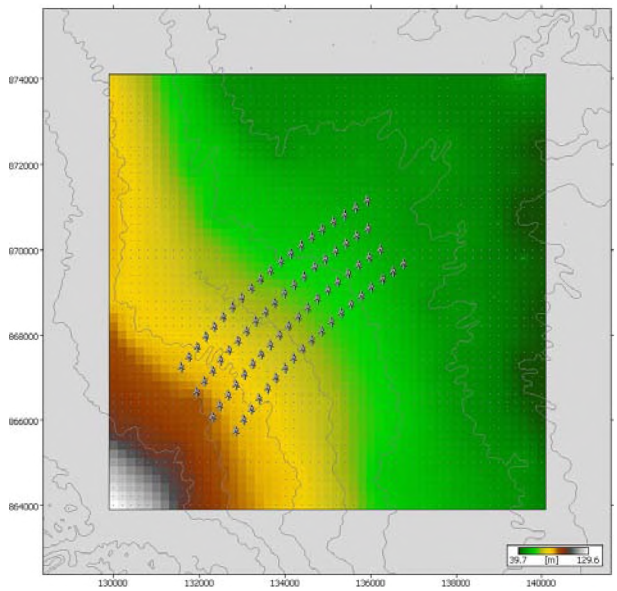


Figure 27. Wind farm C1 seen in the WasP resource grid spatial view. Grid point spacing is 200 m. Color indicates elevation.

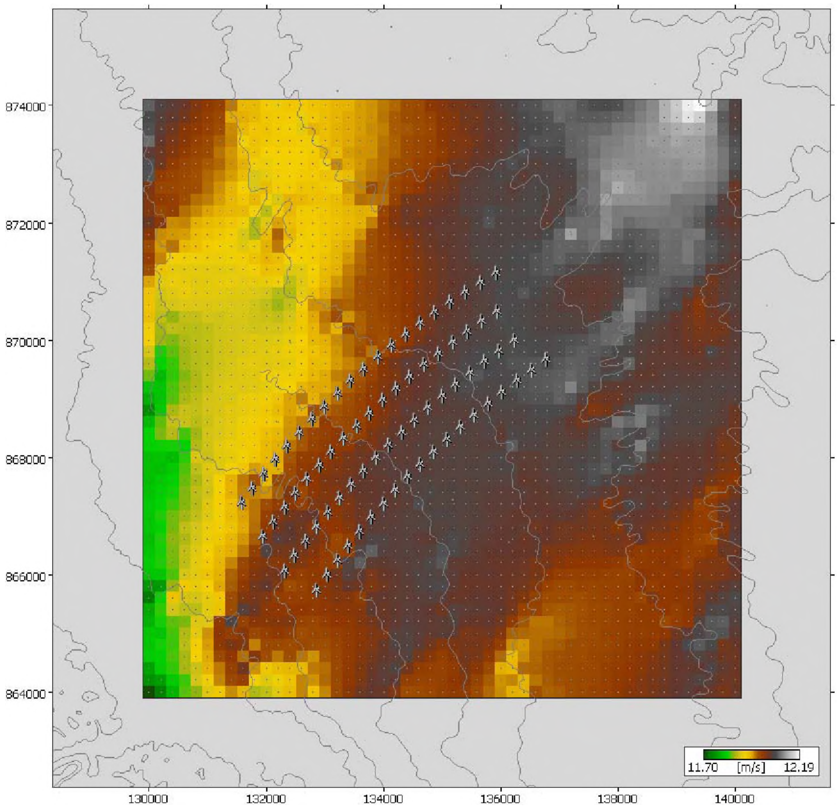


Figure 28. Wind farm C1 as seen in the WAsP resource grid spatial view, with a grid point spacing of 200 m. Color indicates estimates of mean wind speed.

5.5 Power production estimation

The power production estimates for the four different wind farm layouts shown in Figure 25 and Figure 26 are given below. These estimates are based on the regional wind climate at "Gulf of El-Zayt NW".

Wind Farm **L1**	Total	Average	Minimum	Maximum
Net AEP [GWh]	650.340	8.446	8.281	8.694
Gross AEP [GWh]	668.556	8.683	8.630	8.712
Wake loss [%]	2.72	-	-	-

Wind Farm **L2**	Total	Average	Minimum	Maximum
Net AEP [GWh]	650.076	8.443	8.343	8.659
Gross AEP [GWh]	667.386	8.667	8.603	8.709
Wake loss [%]	2.59	-	-	-

Wind Farm **C1**	Total	Average	Minimum	Maximum
Net AEP [GWh]	650.197	8.444	8.298	8.695
Gross AEP [GWh]	668.680	8.684	8.632	8.713
Wake loss [%]	2.76	-	-	-

Wind Farm **C2**	Total	Average	Minimum	Maximum
Net AEP [GWh]	650.141	8.443	8.342	8.658
Gross AEP [GWh]	667.422	8.668	8.606	8.708
Wake loss [%]	2.59	-	-	-

The net annual energy production is about 650 GWh in all four cases, with a wind farm efficiency of more then 97 %.

5.6 Concluding remarks

Wind farm planning in the Gulf of El-Zayt area is in many ways quite simple; however, a few important issues – like the comprehensive, semiannual bird migration through the area – have only been investigated and described in broad terms.

Engineering wind resource assessments and energy production estimation are relatively reliable due to the existence of the four meteorological stations in the El Zayt area, one of which has been operated for extended period as part of the wind atlas projects in the Gulf of Suez. Furthermore, the terrain is quite simple, both with respect to elevation and land-use. The largest uncertainties are therefore related to meso-scale effects and the long-term variation of the wind resource, in particular to what extent such changes will modify or even completely alter the flow patterns found in this area.

The wind resource assessment methodology is based on both high-quality observations *and* state-of-the-art models, which allow for extrapolation of wind resource estimates over most of the region. This, however, is not true for the bird migration studies. While a very important and necessary data material has been established for the Gulf of Suez, we still lack detailed and reliable models and procedures that would make these observations more generally applicable to any wind farm site in the region – i.e. allow for predictions of bird migration patterns and densities to be made for the entire region and at a specific wind farm site.

6 References

[1] Mortensen, N.G., U. Said Said, H.P. Frank, L. Georgy, C.B. Hasager, M. Akmal, J.C. Hansen and A. Abdel Salam (2003). *Wind Atlas for the Gulf of Suez. Measurements and Modelling 1991-2001*. New and Renewable Energy Authority, Cairo; Risø National Laboratory, Roskilde. ISBN 87-550-3195-1. 196 pp.

[2] Diget Christensen, K. & F.P. Jensen. 2003. Bird Migration Atlas of the Gulf of Suez. Hedeselskabet Environment & Energy.

[3] Baha El Din, M. and F.P. Jensen (1999). *Biodiversity Review of the Western Gulf of Suez*. Ornis Consult, Copenhagen. 43 pp.

[4] Jensen, F.P. and K.D. Christensen (*2000). Review regarding Environmental Impact Assessments of wind turbine parks in Egypt*. Ornis Consult, Copenhagen. 27 pp.

[5] Mortensen, N.G., A.M. El-Asrag, M.A.M. Sayed, M.A.A. Hussein and A.M. Awad (2004). *Preliminary Wind Atlas for Egypt*. Egyptian Meteorological Authority (EMA), Cairo; Risø National Laboratory, Roskilde. 189 pp.

[6] Helmut P. Frank (2003). Wind simulations for the Gulf of Suez with KAMM. Risø-I-1970(EN), Risø National Laboratory, Roskilde. 23 pp.

[7] Frank, H.P.; Rathmann, O.; Mortensen, N.G.; Landberg, L. (2001). The numerical wind atlas – the KAMM/WAsP method. Risø-R-1252(EN). 60 p.

[8] Charlotte B. Hasager (2003). Wind Atlas for the Gulf of Suez – Satellite Imagery and Analyses. Risø-I-1969(EN), Risø National Laboratory, Roskilde. 46 pp.

[9] Specific Guidelines for Environmental Impact Assessment of wind turbines and wind farms in Egypt - EEAA Specific Guidelines

[10] Bowen, A.J. and N.G. Mortensen (1996). Exploring the limits of WAsP: the Wind Atlas Analysis and Application Program. Proceedings of the 1996 European Union Wind Energy Conference, Göteborg, Sweden, May 20-24, 584-587.

[11] Landberg, L, S. Frandsen, K. Thomsen, S. Larsen, J. Mann, N.O. Jensen, N.G. Mortensen. Site Assessment – A Guide. [2001], 31 pp. Risø National Laboratory, Roskilde. Report UVE 51171/98-0035

[12] Mortensen, N.G. and E.L. Petersen (1997). Influence of topographical input data on the accuracy of wind flow modelling in complex terrain. Proceedings of the 1997 European Wind Energy Conference, Dublin, Ireland, October 6-9, 317-320.

[13] Troen I., E.L. Petersen. European Wind Atlas. [1989], 656 pp. Risø National Laboratory.

[14] Clausager and Nøhr (1995). Vindmøllers indvirkning på fugle (in Danish) Impact of wind turbines on birds. National Environmental Research Institute report no 147.

[15] Wood, N. (1995). The onset of separation in neutral, turbulent flow over hills. Boundary-Layer Meteorology 76, 137-164.

[16] Biebach, H. 1995. Dangers posed by Wind-power installations at Zaafarana, Egypt, to Bird Migration and Potential Mitigation Measures to reduce their impact. Report to Kreditanstalt für Wiederaufbau (KfW), August 1995.

[17] Hunt, W.G., R.E. Jackman, T.L. Hunt, D.E. Driscoll and L. Culp. 1998. A population study of golden eagle in the Altamont Pass Wind Resource Area: population trend analyses 1997. Report to National Renewable Energy Laboratory. Predatory Birds Research Group, University of California, Santa Cruz.

[18] Longridge, M.W. 1986. The Impact of Transmission Lines on Bird Flight Behaviour with reference to Collision Mortality and System Reliability. Report to Eskom Bird Research Committee, Johannesburg.

[19] Luke, A., Hosmer, A.W. & L. Harrison. 1994. Bird deaths prompt rethink on wind farming in Spain. WindPower Monthly 10, 2: 14 – 16.

[20] McCann, K.I & Wilkins, H.J. 1995. Ariadne-Venus 400kV Transmission Powerline: A study of the annual biology and movement pattern of the three crane species in the KwaZulu/Natal midlands for purposes of aiding in the selection of the route for the Ariadne –Venus 400kV powerline. Eskom and Endangered Wildlife Trust. Unpublished report.

[21] Montes, R. M. & L. B. Jague. 1995. Effects of wind turbine power plants on the avifauna in the Campo de Gibraltar Region. Summary of final report. Sociedad Espanola de Ornitologia (SEO/Birdlife).

[22] Nikolaus, G. 1984. Large numbers of birds killed by electric power lines. Scopus 8: 42.

[23] Orloff, S. and A. Flannery. 1992. Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County wind resource areas. Prepared by BioSystems Analyses, Inc., Tiburon, California, for the California Energy Commission, Sacramento.

[24] Orloff, S. & A. Flannery. 1996. A continued examination of avian mortality in the Altamont Pass Wind Resource Area. Prepared for the California Energy Commision, Sacramento. Prepared by: BioSystems Analysis Inc. Santa Cruz, California. 56 pp.

[25] Shirihai, H. 1996. The Birds of Israel. Academic Press, London. 692 pp.

[26] Thelander, C.G and L. Rugge. 2000. Avian Risk Behaviour and Fatalities at the Altamont Wind Resource Area – March 1998 to Februar 1999. Report to National Renewable Energy Laboratory. Golden, Colorado.

[27] van Rooyen & J.A. Legder. 1999. Bird and utility structures: Develoipments in Southern Africa. In: Ferrer, M. & G.F.E Janss (eds) Birds and Power Lines. Published by Quercus, Madrid. 238 pp.

[28] Winkelman, J.E. 1992. De invloed van de Sep-proefeindcentrale te Oosterbierum (Fr.) op vogels 4. Verstoring. (RIN-report 92/5) DLO-Instituut voor Bos- en Natuuronderzoek, Arnhem. 106 pp.

[29] Hansen, J.C., N.G. Mortensen and U.S. Said (1999). Wind resource modeling for micro-siting – validation at a 60-MW wind farm site. (EWEC '99).

[30] S. Frandsen and C.J. Christensen, "Accuracy of Estimation of Energy Production from Wind Power Plants", Wind Engineering, Vol 16 No. 5. 1992

[31] S. Frandsen and R. Barthelmie, " Local Wind Climate Within and Downwind of Large Offshore Wind Turbine Clusters", Wind Engineering, Vol. 26 No. 1. 2002

[32] A. Crespo et al, "Modelization of a large wind farm considering the modification of the atmospheric boundary layer", EWEC´99

[33] Morten Nielsen: "A Method for Spatial Interpolation of Wind Climates'', EWEC'2001

[34] Jakob Mann, Søren Ott, Bo Hoffmann Jørgensen & Helmuth P. Frank: WAsP Engineering 2000, Risø-R-1356(EN), Risø National Laboratory, August 2002, 90 p., ISBN 87-550-3095-5

[35] *WindPRO internet homepage,* http://www.windpro.com or http://www.emd.dk

[36] Thøgersen, Nielsen, Sørensen, Toppenberg & Christiansen: *Applying New Computer-Aided Tools for Wind Farm Planning and Environmental Impact Analysis*, Proceedings from EWEC 2003 in Madrid.

[37] Hansen, J.C., U.S. Paulsen, A. Hewehy and S. Mansour (1997). Hurghada Wind Energy Technology Center: Background, Facilities and Perspectives. Proceedings of Environment '97, Cairo, Egypt, 16-18 February 1997 (9pp).

[38] Jensen, N.O. (1984). A Note on Wind Generator Interaction. Risø-M-2411, Risø National Laboratory, Roskilde. 16 p.

[39] Katic, I., J. Højstrup, and N.O. Jensen (1986). A Simple Model for Cluster Efficiency. Proceedings of EWEC'86, Vol. I, 407-410.

Annex 1: A selection of Best Practice Guidelines

Great Britain

Best Practice Guidelines for Wind Energy Development. London: British Wind Energy Association. November, 1994. ISBN 870054216, 24 pages. www.bwea.com/pdf/bpg.pdf

Republic of Ireland

Guidelines for Wind Energy Development

The Department of Environment, Heritage and Local Government- August 2004 102 pages. www.environ.ie/DOEI/doeipub.nsf/0/9077dc4f1acf8f1c80256ee60031c31b/$FILE/Draft Wind Energy.pdf

Europe

European Best Practice Guidelines for Wind Energy Development. Brussells: European Wind Energy Association. 1999. 26 pages. www.ewea.org/doc/BPG.pdf

Australia

Best Practice Guidelines for Implementation of Wind Energy Projects in Australia. March, 2002. 101 pages. www.auswea.com.au/downloads/AusWEAGuidelines.pdf

United States

Permitting of Wind Energy Facilities: A Handbook. Washingtn, DC: National Wind Coordinating Committee. August, 2002. 50 pages. www.nationalwind.org/pubs/permit/permitting2002.pdf

Annex 2: List of relevant IEC-standards

Publications issued by TC 88

Publication **Language**

IEC 61400-1 (1999-02) English

Wind turbine generator systems - Part 1: Safety requirements

Maintence Result Date: 2002-02-28

IEC 61400-2 (1996-04) English and French

Wind turbine generator systems - Part 2: Safety of small wind turbines

Maintence Result Date: 2004-04-30

IEC 61400-2 (1996-04) Spanish

VERSION OFICIAL EN ESPANOL - Aerogeneradores. Parte 2: Seguridad de los aerogeneradores pequeños.

Maintence Result Date: 2004-04-30

IEC 61400-11 (2002-12) English

Wind turbine generator systems - Part 11: Acoustic noise measurement techniques

Maintence Result Date: 2004-12-31

IEC 61400-12 (1998-02) English

Wind turbine generator systems - Part 12: Wind turbine power performance testing

Maintence Result Date: 2004-02-28

IEC/TS 61400-13 (2001-06) English

Wind turbine generator systems - Part 13: Measurement of mechanical loads

Maintence Result Date: 2004-06-30

IEC 61400-21 (2001-12) English and French

Wind turbine generator systems - Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines

Maintence Result Date: 2005-12-31

IEC 61400-21 (2001-12) Spanish

Versión Oficial en Español - Aerogeneradores. Parte 21: Medida y evaluación de las características de la calidad de suministro de las turbinas eólicas conectadas a la red.

Maintence Result Date: 2005-12-31

IEC/TS 61400-23 (2001-04) English

Wind turbine generator systems - Part 23: Full-scale structural testing of rotor blades

Maintence Result Date: 2003-05-31

IEC/TR 61400-24 (2002-07) English

Wind turbine generator systems - Part 24: Lightning protection

Maintence Result Date: 2007-07-11

IEC WT 01 (2001-04) English

IEC System for Conformity Testing and Certification of Wind Turbines - Rules and procedures

Work in progress by TC 88

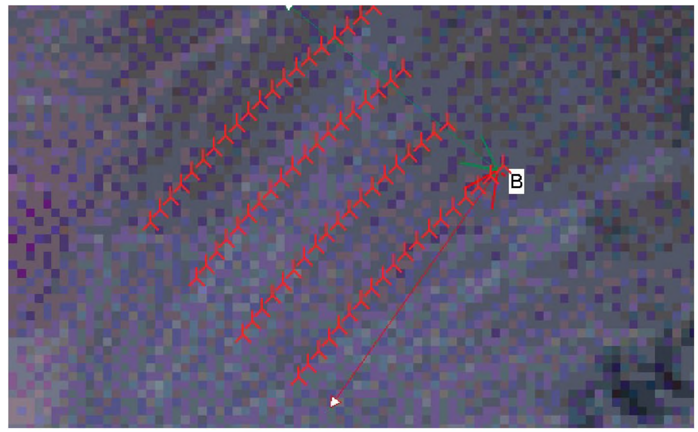
Project	Lang. code	Stage code
IEC 61400-1 Ed. 3.0	E	CDM
Wind turbines - Part 1: Design requirements		
IEC 61400-2 Ed. 2.0	E	CDM
Wind turbine generator systems - Part 2: Design requirements for small wind turbines		
IEC 61400-3 Ed. 1.0	E	ANW
Wind turbine generator systems - Part 3: Design requirements for offshore wind turbines		
IEC 61400-4 Ed. 1.0	E	ANW
Design requirements for gearboxes for wind turbines		
IEC 61400-11am.1 Ed. 2.0	E	AMW
Amendment 1 to IEC 61400-11: Wind turbine generator systems - Part 11: Acoustic noise measurement techniques		
IEC 61400-14 TS Ed. 1.0	E	ACDV
Wind turbines - Declaration of sound power level and tonality values		
IEC 61400-25 Ed. 1.0	E	CDM
Wind turbines - Part 25: Communication standard for remote control and monitoring of wind power plants		
IEC 61400-121 Ed. 1.0	E	ACDV
Wind turbines - Part 121: Power performance measurements of grid connected wind turbines		

Annex 3: Visualisation – Case at El Zayt

Project	Description	Printed/Page
Gulf of Suez	Wind Farm Planning in the Gulf of Suez Visualizations for the NREA/Risoe report Risø-R-1387(EN) Note 1: Energi- og Miljødata (EMD) can not be held responsible for direct or indirect economical or other losses, which are caused by errors or omissions in the delivery.	02-12-2003 14:10 / 1 Licensed user **Energi- og Miljødata (EMD)** Niels Jernesvej 10 9200 Aalborg +45 9635 4444 Lars-Bo Albinus Calculated 02-12-2003 12:59/2.3.0.216

VISUAL - Main result

Calculation: Layout 2 Four arches large spacing between each arc



Scale 1:100.000

New WTG   Camera

A Photopoint 1 towards SSW

UTM WGS84 Zone 36	East	North	Z	Clouds	Clear sky (0/8)	Landscape picture file 1280 x 960 pixels
Eye point	533 075	3 086 836	63	Visibility	Normal	K \3114_Risø_Suez_photomontage\Nw\P2170030 JPG
Target point	530 862	3 083 710	-505	Sun	Normal	Lens 35 mm Film 35x26 mm
Photo dir	216°			Wind dir	35°	

B Photopoint 1 towards NNW

UTM WGS84 Zone 36	East	North	Z	Clouds	Clear sky (0/8)	Landscape picture file 1280 x 960 pixels
Eye point	533 075	3 086 836	63	Visibility	Normal	K \3114_Risø_Suez_photomontage\Nw\P2170033 JPG
Target point	530 240	3 089 068	-489	Sun	Normal	Lens 35 mm Film 35x26 mm
Photo dir	310°			Wind dir	35°	

C Photopoint 2 towards SSW

UTM WGS84 Zone 36	East	North	Z	Clouds	Clear sky (0/8)	Landscape picture file 1280 x 960 pixels
Eye point	539 794	3 091 964	49	Visibility	Normal	K \3114_Risø_Suez_photomontage\N\P2170125 JPG
Target point	537 459	3 088 918	-441	Sun	Normal	Lens 35 mm Film 35x26 mm
Photo dir	218°			Wind dir	35°	

Continued on next page...

Project:
Gulf of Suez

WTGs: 77

Recommended observation distance: 26 cm

Photo exposed: 06-06-2002 16:30:00
Lens: 35 mm Film: 35x26 mm Pixels: 1280x782
Eye point: UTM WGS84 Zone: 36 East: 533.075 North: 3.086.836
Wind direction: 35° Direction of photo: 216°
Camera: Photopoint 1 towards SSW
Photo: K:\3114_Risø_Suez_photomontage\Nw\P2170030.JPG

Energi- og Miljødata (EMD)
Niels Jernesvej 10
9200 Aalborg
+45 9635 4444
Lars-Bo Albinus

Project
Gulf of Suez

WTGs: 77

Recommended observation distance: 26 cm

Photo exposed: 06-06-2002 16:30:00
Lens: 35 mm Film: 35x26 mm Pixels: 1280x782
Eye point: UTM WGS84 Zone: 36 East: 533.075 North: 3.086.836
Wind direction: 35° Direction of photo: 310°
Camera: Photopoint 1 towards NNW
Photo: K:\3114_Risø_Suez_photomontage\Nw\P2170033.JPG

Energi- og Miljødata (EMD)
Niels Jernesvej 10
9200 Aalborg
+45 9635 4444
Lars-Bo Albinus

Project:
Gulf of Suez

WTGs: 77

Recommended observation distance: 26 cm

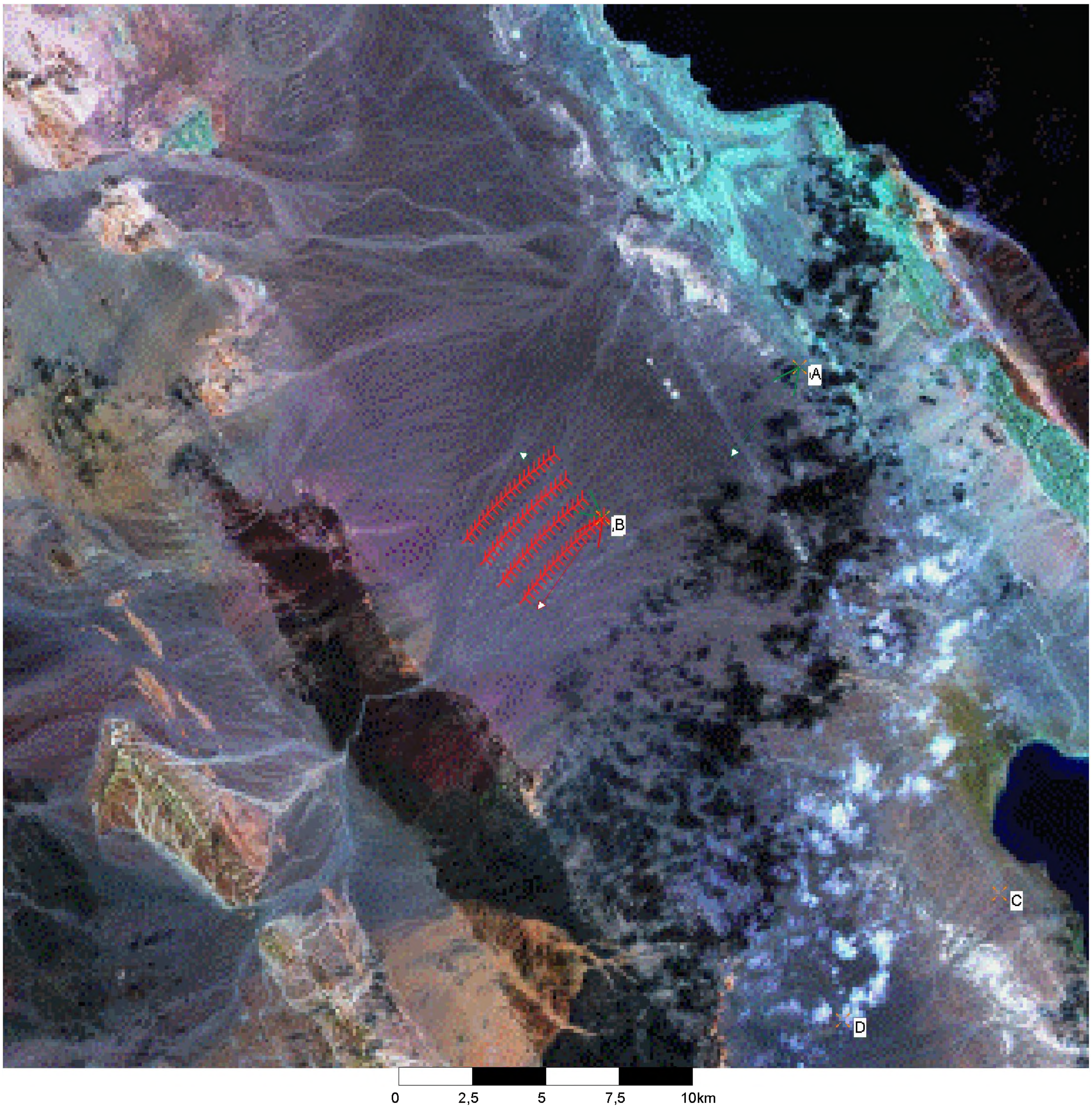
Photo exposed: 06-06-2002 17:10:00
Lens: 35 mm Film: 35x26 mm Pixels: 1280x782
Eye point: UTM WGS84 Zone: 36 East: 539.794 North: 3.091.964
Wind direction: 35° Direction of photo: 218°
Camera: Photopoint 2 towards SSW
Photo: K:\3114_Risø_Suez_photomontage\N\P2170125.JPG

Energi- og Miljødata (EMD)
Niels Jernesvej 10
9200 Aalborg
+45 9635 4444
Lars-Bo Albinus

Project	Description	Printed/Page
Gulf of Suez	Wind Farm Planning in the Gulf of Suez Visualizations for the NREA/Risoe report Risø-R-1387(EN) Note 1: Energi- og Miljødata (EMD) can not be held responsible for direct or indirect economical or other losses, which are caused by errors or omissions in the delivery.	02-12-2003 14:10 / 7 Licensed user **Energi- og Miljødata (EMD)** Niels Jernesvej 10 9200 Aalborg +45 9635 4444 Lars-Bo Albinus Calculated 02-12-2003 12:59/2.3.0.216

VISUAL - Gulf of Suez (large)

Calculation: Layout 2 Four arches large spacing between each arc **File:** SulfOfSuez_Large.tif



Map: , Print scale 1:200.000, Map center UTM WGS84 Zone: 36 East: 531.099 North: 3.086.102

New WTG   Control point   Camera