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Isolated Systems with Wind Power
An Implementation Guideline

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Abstract The overall objective of this research project is to study the development of methods and guidelines rather than "universal solutions" for the use of wind energy in isolated communities. So far most studies of isolated systems with wind power have been case-oriented and it has proven difficult to extend results from one project to another, not least due to the strong individuality that has characterised such systems in design and implementation.

In the present report a unified and generally applicable approach is attempted in order to support a fair assessment of the technical and economical feasibility of isolated power supply systems with wind energy.

General guidelines and checklists on which facts and data are needed to carry out a project feasibility analysis are presented as well as guidelines how to carry out the project feasibility study and the environmental analysis.

The report outlines the results of the project as a set of proposed guidelines to be applied when developing a project containing an application of wind in an isolated power system. It is the author's hope that this will facilitate the development of projects and enhance electrification of small rural communities in developing countries.

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Preface

The present project has been financed by the Danish Ministry of Energy under the energy research programme (EFP97), jour. no. 1363/0022.

Until now studies of isolated systems with wind power have mostly been case-oriented. Thus it has been difficult to extend results from one project to another, not least due to the strong individuality that has so far characterised such systems and their implementation. Therefore, a main objective of the present project is to develop and present a more unified and generally applicable approach for assessing the technical and economical feasibility of isolated power supply systems with wind energy. As a part of the project the following tasks were carried out: Review of literature, field measurements in Egypt, development of an inventory of small isolated systems, overview of end-user demands, analysis of findings and development of proposed guidelines.

The project is reported in one main report and four topical reports, all of them issued as Risø reports:

Isolated Systems with Wind Power
- *Main Project Report (Risø R-1256)*
- *Implementation Guideline Report (Risø R-1257)*
- *Review of Relevant Studies of Isolated Systems (Risø R-1109)*
- *Results of Measurements from Egypt (Risø R-1240)*
- *Inventory of Isolated Systems in Egypt (Risø, I-1703)*

The present report is the Implementation Guideline Report Risø R-1257, presenting a unified and generally applicable approach for assessing the technical and economical feasibility of isolated power supply systems with wind energy.

The guideline is a living document that should be updated when significant developments in the technology or the market conditions and commercial activities occur. The present report is the first version. Please send your comments and contributions by email to windconsult@risoe.dk or fax +4546775083 att: Niels-Erik Clausen. Thank you.

Glossary

BOO	Build - Own - Operate
BOOT	Build - Own – Operate - Transfer
COE	Cost of energy
DGS	Diesel Generator Set
DRE	Decentralised Renewable Electrification
EDF	Electricité de France
EMS	Energy Management System
ESMAP	WB Energy Sector Management Assistance Programme
ETDE	Energy Technology Data Exchange
EWDS	European Wind Diesel Software Package
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
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
LTMC	Long term marginal cost
NPV	Net present value
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 Programme
VOE	Value of Energy
WB	World Bank
WD	Wind-diesel
WECS	Wind Energy Conversion System
WMO	World Meteorological Organisation
WTG	Wind Turbine Generator

1 Introduction

The project is based on the assumptions that isolated systems with a high degree of wind energy penetration constitute technically reliable options and that they can be made cost-competitive in the near future. In addition, it is assumed that such systems have their major market potential both as distributed generation in large utility grids in the developed world and as local power supply in 1st, 2nd and 3rd world countries.

In both applications such systems are subgroups of systems that are often referred to as Decentralised Renewable Electrification (DRE) systems. In the basic form, where wind turbines are connected to local diesel power stations, the systems are referred to as Wind Diesel (WD) systems. In the more general form, where several renewable energy sources and support technologies may be included, the systems are frequently referred to as Integrated Hybrid Renewable Energy (IHRE) Systems.

1.1 Background

The background for the project is the perception that there is a large potential world wide for energy supply to remote and isolated villages with local power supply systems characterized by large wind resources and high energy production costs.

In such places the inclusion of wind energy in the energy production can be very attractive and beneficial, but best practices for project implementation are missing in terms of

- Overview of methodologies and tools
- Documented examples of cases and potential locations
- Functional outlines of guidelines based on practical experience
- Realistic implementation strategies aimed at market formation

The project aims at addressing all these issues in an attempt to present a unified and generally applicable approach for assessing the technical and economical feasibility of isolated power supply systems with wind energy. Each issue is addressed in a separate project report, and this report is the report on functional guidelines for isolated systems with a high proportion of wind energy.

1.2 Objectives

The overall objective of the present report is to assist the dissemination of the use of wind energy in isolated communities by contributing to the development of operational engineering design- and assessment methods for isolated electricity supply systems with a large contribution of wind energy by presenting an outline of a functional set of guidelines and recommendations based on practical experience.

The difference between guidelines and standards is illustrated by the two types of documents, that are now being developed in the framework of the IEC:

Guidelines deal with project implementation related elements of DRE systems and may include guidelines for system selection, bid and contract, quality assurance, operation, maintenance and overall system classification. Several versions of project implementation guidelines may be envisaged for various types and classes of systems

Standards deal with the specific technical elements of DRE systems and is the responsibility of individual technical committees in the national and international standardisation framework, that include IEC, CENELEC and other bodies. The standards are unique, and all project implementation guidelines should refer to one and the same set of RE systems standards

These definitions are adopted in the development of IEC/PAS 62111 document (EDF, 1997) for small DRE systems for rural electrification in 3rd world countries.

A basic philosophy of the presented work is that wind energy should only be introduced in power systems when it is applicable and beneficial, rather than introducing wind power for demonstration purposes in projects not well suited for wind energy.

2 State of the Art - Technology

The main purpose of the first part of this section is to uncover "state of the art" from a technical point of view. The second part sets up a framework on how to characterise power systems with wind energy.

2.1 State of the Art

The main focus of this paragraph is on state-of-the-art of wind turbines and power systems with wind power. Since the technical know-how and performance of wind turbines are non-uniform a definition for categorisation of wind turbines will be introduced. Power systems with wind power are assessed by literature.

First of all, wind turbines can be divided into five groups with respect to the range of the nominal power as listed in Table 1. The power limits presented below are approximate and should be seen as a guideline only.

Table 1. Categorisation of wind turbines.

Nominal power	Typical application
< 1kW	Micro's
1-10kW	Wind home
10-200kW	Hybrid/Isolated systems
200-1MW	Grid connected – single or in cluster
> 1MW	Offshore (or onshore) wind farms

The present *state of the art* on wind turbines has been analysed in (L.H.Hansen et al., 2001). The main results are listed in Table 2, outlining the applied concept of the two largest turbines from each manufacturer of the top-8 suppliers world wide.

Table 2. Applied concept of the two largest (i.e. newest) wind turbines from each manufacture of the top 8 suppliers world wide. Source [Hansen et al., 2001].

Manufacturer (top 8 supp.)	**Wind turbine**	**Cofigu-ration**	**Power control features**	**Comments**
NEG Micon (Denmark)	NM 2000/72	a	Active stall	Two speed
	NM 1500C/64	a	Stall	Two speed
Vestas (Denmark)	V80 – 2 MW	c	Pitch and variable speed	Range: 905 rpm. to 1915 rpm.
	V66 – 1.65 MW	b	Pitch and OptiSlip	Range: 1500 rpm. to 1650 rpm.
Gamesa (Spain)	G52 – 850 kW	c	Pitch and variable speed	Range: 900 rpm. to 1650 rpm.
	G47 – 660 kW	c	Pitch and variable speed	Range: 1200 rpm. to 1626 rpm.
Enercon (Germany)	E-66 – 1.8 MW	d	Pitch and variable speed	Gearless. Range: 10 rpm. to 22 rpm.
	E-58 – 1 MW	d	Pitch and variable speed	Gearless. Range: 10 rpm. to 24 rpm.
Enron Wind (USA)	1.5s – 1.5 MW	c	Pitch and variable speed	Range: 989 rpm. to 1798 rpm.
	900s – 900 kW	c	Pitch and variable speed	Range: 1000 rpm. to 2000 rpm.
Bonus (Denmark)	2 MW	a	Active stall	Two speed
	1.3 MW	a	Active stall	Two speed
Nordex (Germany)	N80/2500 kW	c	Pitch and variable speed	Range: 700 rpm. to 1303 rpm.
	N60/1300 kW	a	Stall	Two speed
Dewind (Germany)	D4 – 600 kW	c	Pitch and variable speed	Range: 680 rpm. to 1327 rpm.
	D6 – 1.25 MW	c	Pitch and variable speed	Range: 700 rpm. to 1350 rpm.

The letter concerning the configuration in Table 2 denotes:

a) a fixed speed wind turbine using an asynchronous generator with cage rotor, a soft starter and a battery bank for reactive power compensation.

b) a variable speed wind turbine using a doubly fed asynchronous generator implemented in a setup known as OptiSlip (used by Vestas since the mid 1990's).

c) a variable speed wind turbine using a doubly fed asynchronous generator where the rotor is connected to the grid through a frequency converter.

d) a gearless variable speed wind turbine using a multipole wound synchronous generator, where the stator is connected to the grid through a frequency converter and the rotor through a rectifier.

Based on the findings in [Hansen et al., 2001], the present "state-of-the-art" large wind turbine is a 3 bladed upstream machine with tubular tower using:

- active stall with a two speed asynchronous generator, or
- pitch control combined with variable speed. Moreover, the variable speed concept is mainly realised using configuration "c", i.e. a doubly fed induction generator with a rotor connected IGBT based frequency converter.
- only one of the top-10 manufactures is building a gearless (variable speed) wind turbine.

The above characteristics are for a typical main-stream wind turbine. Besides that a number of alternative wind turbine designs exist. As described in (L.H.Hansen et al., 2001) Lagerwey is using configuration "d", but with a 6 phased wound synchronous generator. Nordic Windpower promotes configuration "a" in a two bladed upwind version. And Gaia is using configuration "a" in a two bladed downwind version. Vergnet is also using configuration "a", in a two bladed as both upwind or downwind versions. Scanwind has started the construction of a wind turbine using a configuration with a permanent magnet synchronous generator based on the Windformer and a DC grid.

The present *state of the art* of power systems with wind energy is more difficult to assess. Findings in (A.L.Pereira, 2000) will be quoted to give an impression. In Table 3 an overview of hybrid power systems at research facilities throughout the world are listed, while Table 4 presents hybrid power systems installed throughout the world during the last decade.

Table 3. Selected list of hybrid power systems at research facilities. Source [Pereira, 2000].

Lab. / Country Installation year	Diesel (kW)	WTG (kW)	Dump load	Consumer load	Storage (kWh)	Features
NREL / USA 1996	2 x 60	1 x 20[a] 1 x 75[a] 1 x 20[c] 1 x 10[e] 1 x 50[f]	–	100kW	16 (24V) 180 (120V)	3 AC buses 3 DC buses PC based control system Advanced data acquisition system
CRES /Greece 1995	1 x 45	1 x 30[a]	45	20kVA	–	PC based control system
DEWI /Germany 1992	1 x 30	1 x 50[a] 1 x 30[b]	?	75kVA 127 x 1kW	?	?
RAL /England 1991	1 x 85	1 x 45[b]	72kW	48kW	45 (flywheel)	Dedicated microcomputer controller PC data-logging system
EFI /Norway 1989	1 x 50	1 x 55[a] 1 x 55[b]	55kW	40kW 20kVAr	27	Dedicated microcomputer controller Data acquisition w/ transient recorder
RERL–UMass / USA 1989	1 x 15	1 x 15[a]	16kW (1994)	16kW (1994)	–	PC based control system 4 operating strategies Advanced data acquisition

						system (1994) Rotary converter AC-DC-AC
IREQ /Canada 1986	1 x 35	1 x 50[e]	17kW	50kW	–	–
AWTS /Canada 1985	2 x 50	1 x 40[b] 1 x 35[c] 1 x 65[d] 1 x 80[e] 1 x 50[f]	190kW	115	–	–
RISØ /Denmark 1984	1 x 30	1 x 55[b]	75kW	–	30 (400V) (1997)	PC based control system Sophisticated data acquisition system

Notes: (a) wind turbine simulator; (b) fixed speed induction generator; (c) VAWT, fixed speed induction generator; (d) two speed induction generator; (e) variable speed synchronous generator; (f) downwind fixed speed induction generator.

Table 4. Selected list of relevant hybrid power systems installed throughout the world in the last decade. Source [Pereira, 2000].

Site / Country Operation period	Diesel (kW)	WTG (kW)	Dump load	Other loads (kW)	PV (kW)	Storage (kWh)	Wind penetration
Sal / Cape Verde 1994–2001	2 x 500 1 x 800 1 x 620 1 x 400	2 x 300	–	2 x 250 (RO desalination) 1 x 60	–	–	22% (month) 14% (3years)
Mindelo / Cape Verde 1994–2001	2 x 2300 2 x 3300	3 x 300	–	1 x 250 (RO) 1 x 500 (RO) 2 x 400-750	–	–	17% (month) 14% (3years)
Dachen Island / China 1989–2001	1 x 280 1 x 256 2 x 100 1 x 560	3 x 55 2 x 20	127	–	–	–	26% (month) 15% (years)
Fuerteventura / Canary Island 1992–2001	2 x 75	225	100	16.5 (RO) 8 (Ice) 70 (Lights)	–	–	?
Foula Island / Shetland Islands 1990–2001	1 x 28 1 x 18 (hydro)	1 x 60	90 25	96 (heating)	–	1400 (hydro)	70% (3months)
La Desirade / Guadeloupe 1993–2001	1 x 160 3 x 240	12 x 12	–	–	–	–	40% (instantaneous)
Marsabit / Kenya 1988–2001	1 x 100 1 x 200	150	–	–	–	–	46% (3years)
Cape Clear / 1987–1990	1 x 72	2 x 30	–	–	–	100	70% (instantaneous)
Rathlin Island / Northern Ireland 1992–2001	1 x 48 1 x 80 1 x 132	3 x 33	–	–	–	73	100% (instantaneous) 70% (year)
Kythnos Island / Greece 1995–2001	3 x 125 2 x 250 3 x 633	5 x 33 1 x 150	–	–	100	330	?
Frøya Island / Norway 1992–1996	1 x 50	1 x 55	72	–	–	27	100% (instantaneous) 94% (8months)
Denham / Australia 1998–	2 x 288 2 x 580	1 x 230	–	–	–	–	70% (instantaneous) 23% (6months)
Lemnos Island / Greece 1995–	2 x 1200 2 x 2700 1 x 2600	8 x 55 7 x 100	–	–	–	–	?

2.2 Categorised Power Systems

In the following a categorisation of power systems is suggested. This is useful as some design characteristics and performance conditions of e.g. a wind turbine in an isolated system in Egypt and a wind turbine situated in an offshore wind farm in Denmark are similar, while others are quite different. Thus it is beneficial to introduce a division of the power systems into a number of groups or categories according to the installed power capacity.

Four groups are listed in Table 5 using the installed power as the main key.

Table 5. Categorisation of power systems.

Installed Power	Category
< 1kW	Micro systems
1-100kW	Wind home systems
100 kW -10MW	Island/Isolated systems
> 10MW	Wind Power Plant systems

The installed power presented in Table 5 should be seen as indicative of the order of magnitude. Thus a micro system is typically a small wind turbine with a capacity less than 1kW; a wind home system has a typical a capacity between 1 and 100 kW with a wind turbine of 1-50 kW; an isolated power system is typically from 100 kW to 10 MW installed power and with wind turbines in the range from 100 kW to 1 MW, while a wind power plant or a wind farm typically is larger than 10 MW with several wind turbines larger than 500 kW.

The wind penetration level of the power systems presented in Table 4 are plotted in Figure 1 as a function of the installed capacity. The situation in Denmark in 1998 and as planned for the year 2030 have been used as guiding values in case of the very 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 official Danish energy plan

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 is rather high, but not necessarily varying a lot through this range. The main reason for the dramatic drop in wind energy penetration is that energy storage is needed to reach the very high penetration levels and that managers of larger systems will prefer a cautious approach, fearing negative consequences for the existing equipment due to wind power fluctuations.

As indicated by the dotted line in Figure 1, 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 smaller 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 to high degree of complexity and too little experience as a background for the project development. Thus, when gradually increasing the wind energy penetration starting at the dashed line and moving towards the dotted line step-by-step applying simple, robust, reliable and well tested concepts seem to be the recommendable approach.

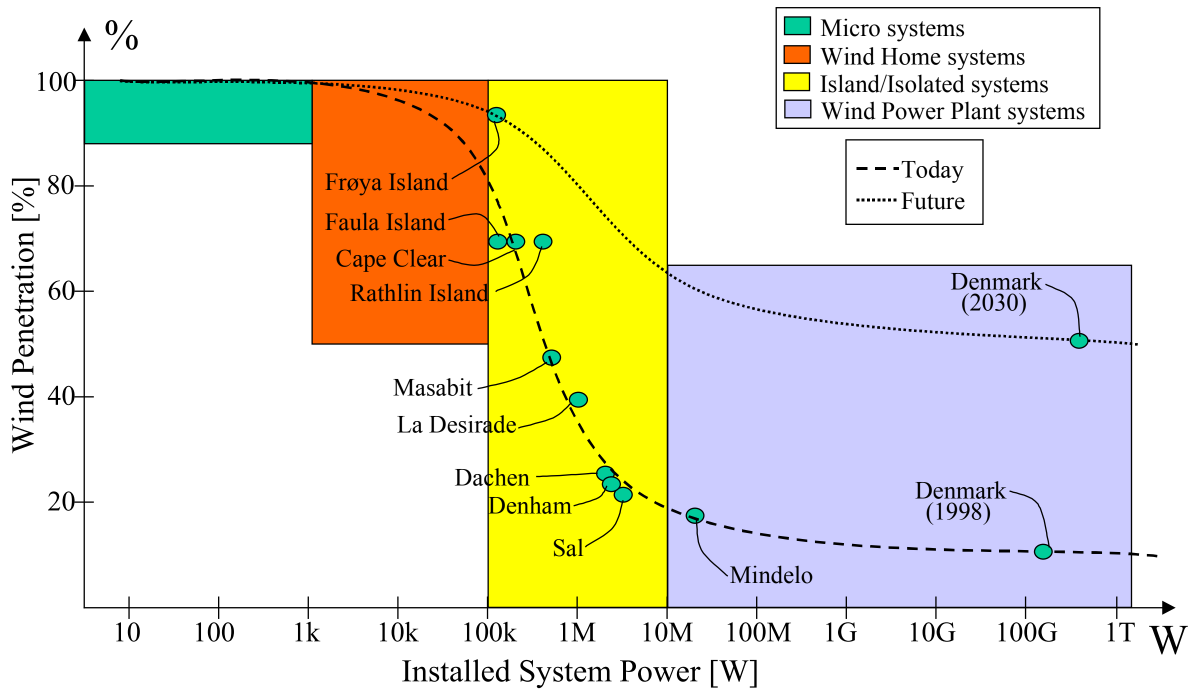

Figure 1. Present and expected future development of the wind energy penetration vs. the installed system capacity.

The guidelines / recommendations stated later in this report are mainly associated with wind home systems and island/isolated systems in the range from 30 kW up to 10 MW installed power.

3 State of the Art – Economics

The economics of isolated systems with wind power is not well documented, but a description includes the following issues:

- Cost of electricity in isolated systems
- Cost of electricity from wind turbines
- Typical electricity production costs of a WD system

Cost of electricity in isolated systems, where existing power supply is typically from diesel power plants, varies over a very wide range:
- Low values of the order 0,20 USD/kWh
- Medium values of the order 0,45 USD/kWh
- High values of the order 1,0 USD/kWh.

Thus the cost of electricity in existing isolated systems is typically many times higher than in large utility grids, where production cost of electricity (taxes not considered) is of the order 0,04 USD/kWh

Cost of electricity from grid connected wind turbines has decreased from typically 0,20 USD/kWh in the early 1980's to now approaching the production costs of 0,04 USD/kWh in large grids. The main parameter influencing the COE from wind turbines is the annual average wind speed.

Electricity production costs from WD systems are not well documented, and they cover a very wide range. Furthermore COE from a WD system may be difficult to ascertain precisely, as the task may be outside the scope of small scale DRE projects. Therefore the economic viability of a WD system will often be assessed by comparing the COE from the wind turbine (including costs of any support technology) with the avoided costs due to fuel saving in the existing diesel system. In case of a retrofit installation of a wind turbine in an existing WD system this may be a fair assessment, however, in the planning phase of a new isolated system the comparison should be based on total cost of electricity including capital cost of the alternatives analysed.

4 Fact Finding

4.1 Wind Resources & Climate

Knowledge of the characteristics of the climate and especially the wind regime is crucial for the design and assessment of a potential project with a content of wind energy. This task should comprise the following:

- Identification of existing long-term measurement of wind speed and direction from a meteorological station. Data should preferably be either in time-series format or in histogram for a period of 3-10 years.
- Assessment of quality of such data
- Extrapolation to potential application sites – by WAsP or WAsP derived tools
- Identification of sites for additional wind measurements
- Planning and execution of dedicated wind measurements (see (B.H.Bailey & S.L McDonald, 1997)
- Obtain maps of the area in digital and paper form. The maps should contain both height contours and land-use (roughness) contours.

During a site visit, the roughness classification should be observed and interpreted based on the maps and the visual inspection.

- at the wind measurement locations and surroundings
- at potential wind farm sites and surroundings
- at existing long term meteorological stations and surroundings

For a good guide to monitoring of wind and data collection see (B.H.Bailey & S.L McDonald, 1997).

Surroundings of sites and meteorological stations means in this respect up to 10 km from the candidate sites for wind turbines and from any meteorological station, where the influence of roughness is significant for the results of the flow modelling. Some useful forms for fact finding are included in appendix A.

4.2 End User Needs and Load Demand

The primary objective of the power system is to supply power in order to provide certain services for the community. The single most important task when designing a power system is the description of the services that are required. The list of services can be quite long however it is necessary for the assessor to produce this list as accurately as possible. This has to be done in close collaboration with the local community/authority. The list should contain both required and desired services for immediate implementation as well as future implementation. Such a list might contain some of the services listed below:

- Domestic: Lighting, TV, refrigerator etc.
- Telecommunication: Repeaters, telephone/fax/internet
- Workshops
- Offices
- Shops
- Hotels
- Desalination plants
- Hospitals/Health clinics
- Schools

Each of the services should be characterised according to the list below

- Energy consumption
- Load profile (day, week)
- Geographical location
- Priority (primary or base, optional, deferrable load)

- Seasonal influence

Having produced a list of services supplied by the power system including the characteristics as above it is possible to aggregate the load for use in the system analysis. Since the estimated load is to be used in both the sizing of the components, determination of the operating strategy and for the technical/economic analysis the important key figures are the minimum and maximum load and the load profile. It is also important to specify the priority of the load in terms of primary, optional and deferrable. If there are significant seasonal variations these have to be quantified as well.

The final part of the specification of the end user need is to provide forecasts for the load. Since improvement of the power supply often results in more people using more energy there will typically be a relatively high growth rate in the demand. The steep increase in the load will of course have a significant impact of the performance of the power system, especially on the ability to supply power even during peak load periods. The load forecast is also used in the planning of grid extensions including analysis of potential interconnection of the isolated grid either to neighbouring grids or to a larger national grid.

The acquisition of consumer load data can be quite difficult especially if the project is electrification. In existing power systems the only data available will often be readings by the operator at the power station e.g. hourly and monthly energy consumption readings. These data are valuable but are not sufficient for a more thorough analysis of advanced operating strategies. Load forecasts can also be estimated based on historical data. In case of electrification the load of the system has to be entirely based on the assumed loads. In this case the systematic approach outlined above is recommended.

4.3 Existing Power Supply

In order to obtain data on the existing power supply and grid it is recommended to prepare a questionnaire. The questionnaire should cover generation, distribution and consumption. There are many applications of the data. These include performance characteristics (e.g. fuel consumption) for system performance assessment, condition of the equipment (e.g. gensets and grid) in view of future use in the system, extension plans etc. An example of a questionnaire is included as appendix D. It can be beneficial to divide the questionnaire in order to have a less detailed one to be used in the initial stage of the analysis and a more detailed one to be used in the final design. Some of the points to be covered are listed below.

- Number of consumers
- Installed capacity, No. generator units, year of commissioning and O&M-status
- For each generating unit specify (base load/ intermediate/ peak load/back-up)
- System operation: manual/automatic
- Diesel genset operation: maximum and minimum load, load sharing
- cosφ at busbar
- grid-frequency and voltage stability limits and control e.g. type of governor and AVR
- Distribution: Breakers, protection level, earthing, transformers
- Grid map: length, cross section, material, overhead lines/cables

- Operational experience: typical faults, number and duration of outages, maintenance schemes
- Fuel consumption
- Operational hours on annual basis
- Total consumption (kWh)
- Diurnal load variation
- Cost of energy, price of energy
- O&M staff, qualifications etc.
- Billing procedures
- Design codes
- Planning codes (guidelines/ manufacturers framework agreements/ etc.)

4.4 Physical Planning & Infrastructure

The possibilities and limitations imposed by the existing physical planning of the community must be taken into account. Examples of issues to be considered include

- Land use and building restrictions
- Development plans for the location in question (land, buildings, industry)
- Permissions needed and ownership issues
- Special protection areas
- Environmental restrictions.

The existing infrastructure and its ability to support the level of technology provided by the prospective project must be carefully assessed. Also basic issues of access roads and load carrying abilities should be evaluated, including issues such as:

- Site access: roads, rails, harbour
- Relevant wind turbine sites: accessibility, distance to applicable grid
- Cost-addition to fuel due to long transport distance
- Sustainability of possible wind turbine equipment: temperature and temperature variations, dust, dirt.
- Access to phone, fax, e-mail.
- Accommodation facilities, for temporary construction team and permanent O&M staff
- Shops where common spare parts and tools can be obtained
- Local presence of electronic and mechanical workshops to produce rudimentary spare parts on the location and carry out emergency repairs

4.5 Development Trends

The introduction of wind power (and several other renewable energy technologies) implies that considerable investments must be made initially, which means a long technical/economical project life time (8 – 10 years or more) in order to obtain a reasonably low COE from the system.

Therefore it is necessary to get as much information as possible about the expected development trends for the community in question, in terms of

- Technical development trends such as expected developments in power consumption / end user needs and expected scenarios for the expansion of power production facilities by utilities.
- Economic development trends such as expected developments in fuel and labour cost, capital costs (interest, inflation rates) and taxes / duties.
- Private projects adding new power plants.

Additional details are offered in Section 6.6.4

5 Project Feasibility Analysis

In the feasibility phase a potential site (or a few sites) are identified for further examination. For the analysis of the technical and economical performance of the isolated or WD system a sketch design of the proposed system is carried out and the scenarios to be studied are identified.

5.1 Wind Resource

Estimation of the wind energy resource potential at a given site should be done using the Wind Atlas method (see (Risø Wind Energy Dept., 2001)). This implies extrapolation of nearby representative wind statistics from a wind measurement station taken at a topographically simple site for a climatologically long enough period to the potential wind farm site.

The assessment of the wind resource and annual energy production requires some or all the following:

- Literature, data from WMO, airports and met stations
- Existing wind turbine production statistics
- Surrounding topography - 1:25000 maps, 5-10km distance
- Assessment of existing wind data and new measurements at the potential sites
- WAsP or a WAsP based wind resource assessment tools (see appendix B)
- Extreme winds and turbulence (from e.g. WAsP Engineering (see (J.Mann et al., 2000))
- Candidate lay-out of wind turbines (co-ordinates of the turbines)
- Power and thrust coefficient curve(s) of the turbines, hub height and rotor diameter of the wind turbines.

5.2 Site Selection

- In general: availability of land, human resources and infrastructure
- Adaptation to the national and local development plans and physical surroundings

- Physical planning - existing and new requirements for the site and surrounding land

- Requirements and limitations set by nearby installations - e.g. airports' obstacle limits
- Electromagnetic interference - e.g. airports' ILS and radio systems, LORAN and VOR systems, SOLAS systems, Microwave links, telecom stations, military installations
- Climate in general - temperature, humidity, etc., and its impact on design requirements e.g. regarding corrosion protection, cooling, tropicalization, protection against low temperatures etc.
- Soil conditions
- Access to site
- Erection - facilities, conditions, need for landscaping

5.3 Electrical Design

During the fact finding the relevant standards and requirements are identified as well as existing grid codes. These standards, requirements and grid codes should cover:

- Safety of personnel
- Quality of supply incl. security of supply, quality of voltage and frequency (variations, distortion, flicker etc.)
- Preferred types of equipment

Using this for each of the scenarios the following is assessed:

- Voltage stability
- Frequency (angular) stability
- Steady state behaviour (load flow)
- Assessment of flicker, harmonics etc.

The analysis is carried out with due consideration to the size of the system under investigation. For small systems the additional costs involved in performing the analysis will often be prohibitive. The approach in this case could be some kind of type approval, factory tests and track records (verified references). For large systems the performance requirements will be more demanding and a detailed analysis is required.

The electrical design should be as detailed as the technical performance is ensured and that cost estimates of the complete system can be done. Sketch design of the system is a requirement both in order to be able proper performance analysis and system costing but also in order to document various designs considered as part of the study.

The sizing of the components should include the spatial and temporal distribution of the load and generation. This information is collected as part of the fact finding.

- Electric grid connection – standards & requirements
- Drawings and specifications of the grid components
- Load distribution in the grid - historical data and forecasts
- Sketch design of grid interconnection of wind farm
- Assessment of potential impact on power quality (applicable standards)
- Power system operation and control system communication
- Grid reinforcement versus wind power

5.4 Technical Performance

The technical performance will be assessed by applying a variety of measures. These measures include overall system performance as well as performance of the individual components of the system. For prospective systems the determination of the performance figures will usually involve system simulations using a variety of models each capable of simulating specific aspects of the system behaviour. This includes screening models, logistic (power flow) models, load flow models, dynamic models and transient models. In order to be able to calculate the specified measures system operating strategies have to be specified and implemented in the relevant models. It is also very important to specify how the performance is verified on the installed system.

5.4.1 Performance Characteristics

By evaluation of the performance characteristics it is possible to compare the various scenarios on system level as well as at a component level. On the system level the most interesting measures are security of supply, total fuel consumption, saved fuel as well as potential and utilised wind energy.

A range of relevant performance characteristics are listed below:

- Conventional generation
  - Power production
  - Running hours
  - Fuel consumption
  - Fuel tank capacity requirements
- Wind energy
  - Potential production
  - Utilized production
  - Capacity factor
- Storage
  - Energy in/out
  - Efficiency
  - Life time consumption e.g. charge cycles
- Power Quality & Grid stability
  - Loss of load expectation/probability
  - Loss of energy
  - Voltage quality
  - Frequency quality
  - Supply reliability
- Production statistics
  - Primary load
  - Optional load
  - Deferrable load
  - Penetration of wind energy
  - Dumped energy

As is observed from the list above the range of performance characteristics is very wide. Some are calculated on a time scale of years and others are calculated at a time scale of sub seconds. In the design and analysis phase of a project these numbers are calculated using simulation models. Due to the very different time scales involved as well as of the different nature of the measures separate models have to be applied. A selection of models are listed in section 5.6.

The use of the performance characteristics is twofold. First of all, they are used directly in the comparison between the scenarios studied. This includes characteristics such as loss of load probability, voltage quality and frequency quality. Secondly, some of the figures are used in the economic performance calculations. These are fuel consumption, utilized wind energy and expected battery lifetime.

5.4.2 System Configuration and Operating Strategy

The system configuration and operating strategy both play an important role in the performance of the system. The objectives of the system can be many and include high quality power supply for communication purposes, maximum fuel saving for environmental purposes and lowest operating cost for economic reasons. The operating strategy also has a significant impact on the conditions of the individual components of the system such as minimum load of the diesels, charge and discharge regime of batteries and voltage variations for the load.

Many considerations have to be taken into account when designing the operating strategy. This include the desired level of automatic operation, the maturity of the system design, the infrastructure of the community served as well as more technical matters such as operating conditions of components and the system objective.

5.4.3 Technical Performance Verification

A major and very difficult task is to specify procedures for the verification of the performance of the system. The main difficulty arises from the fact that the system performance specifications are often based on a complex set of assumptions. These assumptions have to be made in the design phase due to a lack of data on the conditions in which the system will be operating.

One approach is to establish the actual operating conditions as accurately as possible together with measurements of the main system performance measures. The exercise is then to transform the observed system performance at the actual conditions to the conditions specified. This can be done using the same models as applied in the design phase of the project. It is a difficult task and the results will often be open for interpretation. It is recommended to simplify as much as possible the guaranteed performance data and state the proposed procedure for performance verification at an early state in order to maintain a high level of confidence with the project stake holders.

5.5 Economic Performance

It is necessary to distinguish between economic and financial performance.

The analysis of economic performance excludes items such as local taxes and is used to provide the community's decision makers with a basis for comparing the investment in the proposed project with other options, not necessarily related to energy production.

Financial analysis results, where local taxes etc. are included, are used to provide the prospective operator/developer and his financiers with a basis for a decision on whether the financial returns are satisfactory and thus warrants an investment in the project.

Both types of analysis should be based on life cycle cost analyses as described in the IEA recommended practice for estimating COE from wind turbines - see (J.O.G Tande & R.Hunter, 1994).

In a total cost analysis the total power supply system with all installations including wind power is considered. In this case it is possible to estimate overall COE for the entire power production.

In an avoided cost analysis the marginal costs and benefits associated with adding wind power to the existing power supply are considered. In this case the costs of adding the wind turbine is compared to the benefits of replacing part of the fuel consumption of the existing power supply system.

Both technical and economic developments in time should be considered, and if the technical lifetime of the installed technology exceeds the economical life of the project, the salvage value of the equipment at the end of the economic life should be added to the income of the system.

5.5.1 Project costs

All ordinary project costs should be included in the cost analysis to be carried over to the track record for COE of the technology. Ordinary project costs include capital costs, O&M costs etc. as outlined below.

Extraordinary project costs for the demonstration aspects of the project should not be included in the cost analysis. Otherwise the track record of the technology might be confused by the seed money necessary to open the market.

Investment costs

If more accurate data are not available from previous or similar projects one should use generic data based on established practice.

Wind turbines:
- Std cost/MW installed, additional cost for arctic or other modifications
- Infrastructure: Standard add-on (30%) unless specified

Diesel generators:
- Std cost/MW installed, additional cost for arctic, tropical, high altitude etc.
- Infrastructure: Standard add-on (30%) unless specified

Auxiliary equipment :
- Dump load
- Devices for optional/deferrable production (pump, heat, cool, freeze, other)
- Devices for energy storage (batteries, flywheel, pumped storage, other)
- Transportation of equipment

- Erection of equipment
- Training

Running costs

The two major operating costs for the diesel generators are

- Fuel cost. A typical specific fuel oil consumption for small diesel generating sets at high loads is 200 - 250 g/kWh produced (at LHV of 42,7 MJ/kg). For a WD system the diesel generator is often running at low load (<50%) and it is more relevant to consider the fuel consumption as a flow rate (l/h), which is nearly constant at low load. When estimating the fuel cost care should be taken to use the cost delivered at the site and including all applicable taxes.
- Cost of lubricating oil. A typical consumption of lubrication oil is 1-3 g/kWh.

O&M costs

Operating and maintenance costs comprise manpower for operation and maintenance as well as spare parts. Use typical data from similar projects or manufacturers or use generic data based on established practice.

- Wind turbines: Percentage of wind turbine investment per year or cost per kWh produced
- Diesel generators: Percentage / fixed cost per operational hour or cost per kWh produced
- Auxiliary equipment by type (e.g. life time / replacement for batteries)

Retrofit & salvage costs

In general it is recommended to use data from previous or similar projects otherwise one should use generic data based on established practices for

- Wind turbines
- Diesel generators
- Auxiliary equipment (determination of lifetime and replacement frequency for battery storage)
- Other costs

Extraordinary project costs

The extraordinary costs are project costs that are to be covered for a pilot / demo system but should not enter the track record because they are not part of the regular expenses. Extraordinary costs include:

- Engineering support
- Consultancy & supervision
- Planning support
- Project & system monitoring
- Evaluation & reporting

5.5.2 Cost of Energy, COE

The COE should be calculated based on a life cycle cost analysis along the lines of the IEA Recommended Practice for COE from grid connected wind turbines ((J.O.G Tande & R.Hunter, 1994)). Items include

- Financial vs. economic COE
- Discount rate(s)
- Capital costs
- O&M Costs
- Retrofit Costs
- Salvage value
- Levellised COE

5.5.3 Value of Energy, VOE

The VOE is input to a Life Cycle Cost analysis of return on the investment in the project and the operation of the system. Items include

- Baseline scenario for existing power supply
- Cost & price structures, subsidies
- Tariffs, PPA for sales of electricity
- Fuel costs, total & avoided by adding the equipment of the project
- Externalities i.e. incremental costs related to e.g. greenhouse gas abatement

Primary power supply

Primary power supply denotes consumer loads that must (in principle) always be met upon demand. It is characterised by

- VOE according to existing tariffs / PPA
- Industry and household electricity demands
- Street lights and other public demands
- Base loads for e.g. water pumping, desalination, heating, cooling etc.

Optional loads

Optional power supply denotes consumer loads that can be met if and when power is available after the primary load demand is met. It is characterised by

- Utilisation of dump load power for e.g. water pumping, desalination, heating, cooling etc.
- VOE is typically lower than primary power and should be estimated if not included in the tariffs or PPA

Deferrable loads

Deferrable power supply denotes consumer loads that must be met within a certain span of time but may be met if & when power is available after primary load demand is met. It is characterised by

- Utilisation of dump load power for e.g. water pumping, desalination, heating, cooling etc.
- VOE is typically lower than primary power and should be estimated if not included in tariffs or PPA
- If deferrable loads are not met within a certain time span they become primary loads

Externalities

Externalities are the term often used for the values that are associated with renewable energy production but not accounted for in the traditional economic analysis. They include

- Reductions in greenhouse gas emissions. Values are assigned on a national/regional/global level.
- Reduction of harmful air borne emissions e.g. NO_x, SO_2 and particulate emissions. Values are assigned on a regional/local level.
- Reductions in fuel and oil spillage. Values are assigned on a local level
- Reductions in noise levels and other disturbances. Values are assigned on a local level

Externalities can only be included in the assessment of operational economy if they are actually paid for by customers. Externalities may be used to obtain part of the investments on favourable conditions, e.g. from GEF on a global level or by governments on a national level, and in such cases externalities can be included in the assessment of the operational economy of the project.

5.5.4 Development Scenarios

The technical-economical project life associated with implementing wind energy into an isolated power supply system will be many years, frequently up to 20 years. Therefore, the scenario to be analysed should include a development scenario that represents the assumed development in both technical and economical/financial terms.

Technical development includes the development of parameters such as
- Consumer demand in terms of primary and secondary load types
- Generating capacity in terms of e.g. active diesels and their replacements / extensions
- O&M needs as generating capacity ages and expands
- Operating strategy and priorities

Economical development includes the development of parameters such as
- Consumer rates and tariffs
- Fuel costs and prices
- O&M costs as existing generating capacity ages and new capacity is added
- Major repairs / overhaul / retrofit

Financial development includes the development of parameters such as
- Inflation
- Interest rates
- Taxes, duties and deductions

Ideally the development scenario should be represented by tables specifying the assumed values of the above parameters year by year during the entire project life. The technical-economical models used should be able to utilise this information in a life cycle cost analysis.

5.5.5 Assessment of Results

The results of the economic/financial analyses come in the form of annual cash flows specifying the projected expenses and income from the installation and operation of the project. The economic/financial indicators used to assess the results include

- Levelised production cost, LPC (cost/kWh) of wind energy,
- Sort run marginal cost, SRMC (cost/kWh) - with and without the assessed wind power plant.
- Net present value, NPV of the project
- Economic internal rate of return, EIRR (% p.a.) of the project
- Financial internal rate of return FIRR (% p.a.) of the project
- Return on Equity ROE (% p.a.) for the investor
- Simple payback time (years) of the project
- Cost of alternative technologies (relevant for the case considered) e.g. solar, hydro etc.

The results will be assessed by comparing the economic/financial indicators with the criteria / threshold values applied by the investor/financier/donor in question for the project.

5.6 Modelling & Simulation

The technical and economical performance of prospective systems is analysed by computer simulation of the systems, and several types of models are used depending on the characteristics on which the simulation is focused. The main parameter characterising the models is the time scale of the simulation, and we usually distinguish between the following types:

- Screening models give an overall assessment of the performance of the system, without going into very much detail of the specifics in the operation of the system.
- Logistic models focus on predicting the annual power productions, fuel savings and power flows in the system. Logistic models are usually the basis in screening models, and they may be deterministic time series models or probabilistic models that produce probability distributions.
- Dispatch models focus on the dispatch of the various power producing components of the system, i.e. start/stop of diesels etc. Time scale typically minutes to an hour.
- Dynamic models focus on the electromechanical behaviour of the system, i.e. machine dynamics but not electrical switching may be represented. Time scale typical a few seconds to half an hour.
- Transient models focus on electrical transients including switching. Time scale typically seconds to minutes.

System control models focus on a representation of control strategies of the system, or parts of the system. Dispatch type models are usually the basis for system control models.

A number of numerical modelling techniques and models are available for the assessment of technical-economic performance the system. Risø R-1109 presents a review of models, and selected models from the review are briefly described below:

HOMER is a fast & comprehensive village power systems screening model, now (1998) supplemented with the VIPOR model for optimal layout of a supply area into grid connected vs. independently supplied consumers. State of the art in this category, but not publicly available. (P.Lilienthal et al., 1995)

INSEL Offers almost unlimited flexibility in specifying system configurations by allowing the user to specify the connectivity on a component level. Intended as an out-of-house-model. (Renewable Energy Group, 1993)

HYBRID2 The state-of-the-art (1998) time series model for prediction of technical-economical performance of hybrid wind/PV systems. Offers a very high flexibility in specifying the connectivity of systems. Publicly available and quite widely used. (H.J.Green & J.Manwell, 1995)

SIMENERG The only model so far with a very high degree of flexibility in the control / dispatch strategy, using a "market square" approach, where the economically optimal subset of power sources that satisfy the power demand is dispatched in each time step. (C.Briozzo et al., 1996)

WINSYS is a spreadsheet (QPW) based model implementing probabilistic representations of resources and demands. WINSYS incorporates the anticipated technical expansions during its lifetime in the technical performance measures, combined with a traditional economic life cycle cost assessment. Thus WINSYS represents a more real life cycle cost analysis than most other models. It is not commercially available. (J.C.Hansen & J.O.G.Tande, 1994)

ENGINEERING DESIGN TOOLS FOR WIND DIESEL SYSTEMS, This package contains seven European logistic models: SOMES (NL), VINDEC (N), WDILOG (DK), RALMOD (UK) and TKKMOD (FIN). It also includes the modular electromechanical model JODYMOD. (D.Infield, 1994)

PROLOAD A probabilistic load flow analysis code, using Monte Carlo techniques, developed in co-operation with an electrical utility for dimensioning of distribution systems with wind turbines. (J.O.G.Tande et.al., 1999)

RETScreen is a spreadsheet (Microsoft Excel) based analysis and evaluation tool for assessment of the cost-effectiveness of potential projects with renewable energy technologies. The software package consists of a series of worksheets with a standardised layout as well as an online manual and a weather and cost database. The tool is developed by the CANMET Energy Diversification Research Laboratory (CEDRL) and is available from the Website of CEDRL. (CEDRL, 2000)

5.7 Uncertainties and Sensitivity Analysis

As the modelling techniques used imply (often considerable) uncertainties the results should not be taken as an accurate representation of the reality of the future. They should rather be taken as one possible manifestation, and they should be supplemented by an analysis of the impact of the major uncertainties. The most important types of uncertainties are

- Modelling uncertainties
- Input data uncertainties
- Parameter uncertainties

The sensitivity to changes in assumptions and input data is usually ascertained by running the models a number of times, where each time one parameter is changed while the other are kept constant. This way the sensitivity of results to variations in the assumptions is estimated, and this is a very important aspect of the analyses. The results of a sensitivity analysis is usually presented in so-called spider diagrams

5.8 Environmental Scoping

At the same time as carrying out technical and economical analyses, developers should also consider the environmental acceptability of potential sites. The initial environmental acceptability considerations (commonly known as environmental scooping) will mainly be based on studies of existing data. A review of reports, equipment performance specifications and maps of the area should be carried out in order to determine specific technical or environmental issues, developers should be aware of considering existing and emerging national, regional and local planning policies.

The following issues should be addressed at a preliminary level, each of which will be studied in greater detail in subsequent phases of the project development:

- Visual Impact
- Proximity to dwellings (existing and planned)
- Ambient air quality
- Noise
- Sensitive Ecology /rare or endangered species
- Archaeological / historical heritage
- Areas for Recreational use /national parks / reserves
- Interference with telecommunications
- Planning issues e.g. civil and military airports

Scoping document

The scooping phase will briefly review the data already available and identify the environmental issues that will have to be subsequently reviewed in detail. The results are normally summarised in a scooping document or report.

6 Environmental Impact Analysis

In projects, where it is likely that the proposed project will have significant effects on the environment by virtue of factors such as its nature, size or location, it may require a more detailed environmental impact analysis.

A full and comprehensive environmental impact assessment consist of an analysis of the following:

- Policy and legislation framework
- Plant design documented in a project description with emphasis on environmental impact
- Analysis of present or baseline situation (emphasize what is particularly sensitive)
- Environmental impact assessment (Construction phase)
- Environmental impact assessment (Operation phase)
- Analysis of alternatives
- Describe mitigation measures to decrease the environmental impact
- Outline of monitoring in the construction and operation phase.
- Public Consultations

The list of contents above is generally accepted as the basis of a full environmental assessment of a project and is widely used internationally among others by the World Bank and other financial institutions as well as consultants. For reference see the World Bank /IFC Operational Procedure for environmental assessment included in appendix C. In case of large projects it is recommended to follow the full environmental review procedure outlined above, while for small projects and /or projects with a limited impact on the existing environment a reduced scope can be applied. In many such cases the environmental scoping report will be sufficient to satisfy the needs of the stakeholders of the project including the local authorities and the financing body.

The following topics are considered in the environmental analysis:

- Site selection
- Ambient air quality
- Visual and landscape assessment
- Noise assessment
- Assessment of flora and fauna
- Archaeological and historical heritage
- Hydrological assessment
- Interference with telecommunication systems
- Aircraft safety
- Safety assessment
- Traffic management and construction of access roads
- Landscaping and deposit of waste during the construction
- Socio-economic effects

In particular for the main components of the WD plant:

6.1 Diesel Generating Set

- Exhaust Gas Emissions: NO_x SO_2 and particulate matter
- Global warning effects from CO_2
- Noise emission
- Risk of fuel spills
- Disposal of used lubrication oil

6.2 Wind Turbines

- Visual impact
- Noise emission
- Shadows and blinks
- Impact on flora and fauna - e.g. danger for rare species, migrating birds
- Impact on reservation areas, archaeological sites or other special interests
- Probability and consequences of accidents to humans or nature

6.3 Desalination

- Impact of raw water supply on level of aquifer or marine life
- Disposal of conc. and warm brine
- Use of additives to control of scale formation and biocides to prevent organic growth
- Impact on drinking water quality and health aspects

6.4 Battery Storage

- Risk of leaks
- Expected lifetime and disposal after use

6.5 Socio-economic and Sociological Issues

Socio-economic and sociological issues are often neglected in the evaluation of viability of a project. This is due to the fact that the items related to the socio-economic and sociological issues can be difficult to assess and moreover it can be quite difficult to prescribe/estimate a fair price/cost of these items. An important example is environmental externalities.

Nevertheless, evaluation of socio-economic and sociological issues should be quantified and analysed as much as possible. The keywords are identification and quantification of relevant issues. In general terms the methodology therefore comprises two tasks:

1) identify and assess the benefits of rural electrification.
2) quantify the costs of rural electrification.

Examples of socio-economic and sociological issues to be considered are listed below. What is the impact:

- on economic growth.
- on agricultural production and rural industrialisation.
- on the unemployment rate
- on the quality of rural life.
- on incomes and poverty alleviation.
- on migration and birth rates.
- on the environment.

Based on these findings a comparison of benefits and costs can be performed – preferably both on a monetary and a non-monetary manner. The monetary part should of course be added to the economic analysis as project costs. See e.g. (F.Fluitman, 1983) and (World Bank Group, 1998)

7 Institutional and Legal Framework

The importance of institutional issues is illustrated by the fact that it has frequently been demonstrated that technically feasible but institutionally problematic projects will not work. These issues should be paid a proper attention by project developers. Institutional issues denote a range of non-technical issues that are outlined in this section.

7.1 Legal Issues

It is necessary to clarify which (if any) legal framework exists for the utilisation of wind energy in the prospective case of isolated power supply. Issues include:
- Policies & incentives for wind energy
- Rights & conditions to build/erect/install wind energy equipment
- Rights & conditions to connect to busbar / grid / substation
- How and by whom are the policies, incentives, rights and conditions determined?
- Which standards & regulations apply?

7.2 Ownership and Responsibilities

The ownership of the project and subsequent the plant should be clearly defined. Is the owner a
- Utility
- IPP organised as Ltd.
- Co-operative
- BOO/ BOOT scheme

On the rights and obligations of the ownership:
- Rights to connect to the grid and produce power
- Agreements on how to get revenues (PPA)
- Obligation or right to produce/repair/remove/replace/expand

In a project with multiple partners a clear definition of the responsibilities in the development, construction and operation phase of the project is vital for a good progress of the project.

7.3 Stakeholders

The parties with an interest in the project should be identified as well as the nature of their interest

- Community council / local authorities
- Regional / governmental authorities
- Power supply responsible / companies / utilities
- Consumers / consumer groups / consumers with special needs
- Experts / expert groups / associations / knowledge centres
- Industry / manufacturers (local vs. regional / national)
- Neighbours

Outline the structure of interests and try to identify possible conflicts of interest that could jeopardise or delay the project

7.4 Technology Carriers

Identification of parties with a capability to participate in the necessary technology transfer and to make the technology available to the community in question (region / nation). It should be considered how to involve such parties in the project. Potential parties are

- Power supply entities
- Private industry
- Service organisations
- Government agencies
- Universities

7.5 Sustainability / replication

The sustainability and replication potential of the project should be assessed based on institutional issues as well as findings from technical, economical, and market & policy issues.

8 Financing

Before the project sponsor or developer approach a potential investor or a funding agency e.g. a bank or an aid organisation it is recommended to consider the following:

- Prepare a project outline description
- Proposed time schedule for implementation
- Project investment including breakdown in major items
- Relevant economical and financial key figures or indicators for the project

- A draft PPA or other evidence of potential income
- Cost of land (if applicable) and access right / roads
- Environmental scoping report / statement

The sources of project financing are

- Traditional private national sources
- Traditional private international sources
- World Bank / IFC, GEF, PCF
- Other multilateral organisations: Inter-American Development Bank, Asian Development Bank, African Development Bank etc.
- National aid organisations e.g. DANIDA
- Private non-governmental organisations

9 Implementation

An important issue is to select a suitable scheme for implementation of the project. An essential issue is to maintain a clear definition of the responsibility throughout the design, transportation of components, erection and commissioning of the plant. Subsequently in the operation phase it should be clarified which party has the capability to operate, maintain and monitor the plant. Monitoring and reporting including development and assessment of operation patterns is of utmost importance for the further development of isolated power systems.

- Implementation Schemes (turnkey, BOOT, etc.)
- Engineering design of WD Plant
- Identification of local specialists
- Assessment of the need for Ex-pats
- Logistics of spare parts, fuel and lubrication oil
- Establishment of an O&M organisation
- Monitoring and reporting

10 Conclusion and Recommendations

A number of issues have been identified which should be considered when developing a wind power project in an isolated power system. The main characteristics of a successful project may be summarised as follows:

- The use of updated versions of relevant international standards – including the one for decentralised power systems with renewable energies now in progress within the IEC.

- That best practice guidelines for project implementation are applied including common references and relevant experience from recent projects.

- That the wind power project in the isolated system in question is part of a concerted action in a national and international programme rather than an individual project.
- That the wind power technology applied in a small to medium size system follow simple and proven approaches, e.g. by repeating and/or downscaling pilot and demonstration systems with positive track records, which may have been developed from filtering down from large-scale systems any technological achievements adaptable to smaller systems.
- That small systems are developed and specified to apply rugged technology suitable for remote communities.
- That no experimental systems are installed at rural remote communities unless previously thoroughly tested and documented at test benches dedicated to serve as experimental facilities
- That ownership is well defined with a built-in interest identified to ensure long-term interest and funding of operation, maintenance and re-investments when needed.
- That an organisation is established with the necessary capacity and capability for implementation, operation and maintenance, preferably including the back-up from a relevant national or regional knowledge centre.
- That a sufficiently detailed feasibility study has been performed.
- That modelling assumptions, input data and methodology applied for the feasibility study and system design reflect the true hardware reality for the types of systems in question

The technical capacity to design, build and operate isolated power systems with a high penetration of wind power exists, but the mature product and the market have not yet met. Nevertheless, there is today an industry offering small wind turbines (10 - 300kW) for hybrid system applications with a long-term commitment in this business. This indicates their belief that a market is emerging so that interest also from some of the large wind turbine manufacturers can be expected.

The above recommendations are seen as moves that would all lead in the direction of a development of the use of wind power in isolated power systems. This will open up and extend access to electricity for the benefit of the development of small rural communities.

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Appendix A Tables and Forms for Fact Finding

WAsP	**Site Description Form**

Name of site/station:

Visited by:	Date:

Geographical reference

Latitude:	Longitude:
Map sheet:	Magnetic declination:

Anemometer set-up

Anemometer height: m a.g.l.	Type/make:
Mast type/Ø:	Averaging period: min.
Boom direction:	Boom length:

Map reference

Map projection:	Map datum:

Site *X:* m	Site *Y:* m	Site *Z:* m a.s.l.

Site/station visit check list

- ❑ Anemometer height verified
- ❑ Station history investigated
- ❑ Data acquisition system check
- ❑ Sector photos: 8 or 12 sectors
- ❑ Mast and instrument photographs
- ❑ DAS clock check, offset:

Additional information

WAsP	**Data Description Form**

Name of met. station:

Prepared by:	Date:

Data file reference

File name:	Data period:
# of observations:	Data recovery rate: pct.
Data format:	Columns for U and D :

Wind speed data

Observation interval: min.	Averaging period: min.
Calm threshold:	Calm indication:
Discretisation:	Missing data flag:

Wind direction data

❑ Relative to geographic north	❑ Relative to magnetic north

Observation interval: min.	Averaging period: min.
Calm threshold:	Calm indication:
Discretisation:	Missing data flag:

Additional information

WAsP	**Obstacle Description Form**

Name of site:

Visited by:	Date:

#	α_1	R_1	α_2	R_2	H	d	P	Comments

Note: α_1 and α_2 are given in degrees clockwise from north and R_1, R_2 , h and d in metres.

WAsP	**Roughness Description Form**

Name of site:

Visited by:	Date:

#	D	z_{01}	X_1	z_{02}	X_2	z_{03}	Comments
1	000						
2	030						
3	060						
4	090						
5	120						
6	150						
7	180						
8	210						
9	240						
10	270						
11	300						
12	330						

Note: z_0 and X are given in metres. Roughness descriptions may also be given as map data.

Additional information

Appendix B WAsP

What is WAsP?

WAsP is a PC-program for the vertical and horizontal extrapolation of wind data. It contains several models to describe the wind flow over different terrains and close to sheltering obstacles. WAsP consists of five main calculation blocks:

Analysis of raw data. This option enables an analysis of any time-series of wind measurements to provide a statistical summary of the observed, site-specific wind climate. This block is implemented in a separate tool, the OWC Wizard.

Generation of wind atlas data. Analysed wind data can be converted into wind atlas data sets. In a wind atlas data set the wind observations have been 'cleaned' with respect to site-specific conditions. The wind atlas data sets are site-independent and the wind distributions have been reduced to standard conditions.

Wind climate estimation. Using a wind atlas data set calculated by WAsP or one obtained from another source – e.g. the European Wind Atlas – the program can estimate the wind climate at any specific point by performing the inverse calculation as is used to generate a wind atlas. By introducing descriptions of the terrain around the predicted site, the models can predict the actual, expected wind climate at this site.

Estimation of wind power potential. The total energy content of the mean wind is also calculated by WAsP. Furthermore, an estimate of the actual, annual mean energy production of a wind turbine can be obtained by providing WAsP with the power curve of the wind turbine in question.

Calculation of wind farm production. Given the thrust coefficient curve of the wind turbine and the wind farm layout, WAsP can finally estimate the wake losses for each turbine in the farm and thereby the net annual energy production of each wind turbine and of the entire farm, i.e. the gross production minus the wake losses. The program thus contains analysis and application parts, which may be summarised in the following way: The WAsP models and the wind atlas methodology are described in more detail in the European Wind Atlas.

Analysis

time-series of wind speed and direction —> wind statistics

wind statistics + site description —> wind atlas data sets

Application

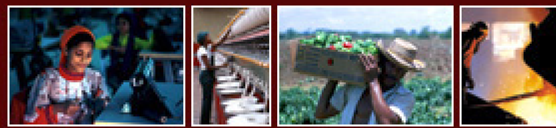
wind atlas data + site description —> estimated wind climate

estimated wind climate + power curve —> estimated power production

Wind farm production

est. power productions + wind turbine and farm characteristics —> gross and net annual energy production of each turbine and of wind farm

Appendix C Environmental Assessment



Environmental Assessment (OP 4.01, October 1998)

Note: OP 4.01 replaces the policy elements of IFC's Environmental Analysis and Review of International Finance Corporation Projects (Washington, D.C.: IFC, 1993). IFC's Procedure for Environmental and Social Review went into effect as of September 1, 1998. Instructions to staff on public consultation and disclosure are contained in IFC's Policy on Disclosure of Information (Washington, D.C.: IFC, 1997). Additional information related to this OP is provided in the Environmental Assessment Sourcebook (Washington, D.C.: World Bank, 1991) and subsequent updates available from the Environment Sector Board and in the Pollution Prevention and Abatement Handbook. Other IFC policies that relate to the environment include *OP 4.04, Natural Habitats; OP 4.09, Pest Management; OP 4.10, Indigenous Peoples (forthcoming); OP 4.11, Safeguarding Cultural Property in IFC-Financed Projects (forthcoming); OP 4.12, Involuntary Resettlement (forthcoming); OP 4.36, Forestry; OP 4.37, Safety of Dams (forthcoming), and OP 7.50, Projects on International Waterways*.

Questions may be addressed to the Associate Director, IFC's Environment and Social Development Department. Additional copies are available to IFC staff in the Information Resources Center, Room L-124.

Environmental Assessment

1. IFC[1] requires environmental assessment (EA) of projects proposed for IFC financing to help ensure that they are environmentally sound and sustainable, and thus to improve decision making.

2. EA is a process whose breadth, depth, and type of analysis depend on the nature, scale, and potential environmental impact of the proposed project. EA evaluates a project's potential environmental risks and impacts in its area of influence;[2] examines project alternatives; identifies ways of improving project selection, siting, planning, design, and implementation by preventing, minimizing, mitigating, or compensating for adverse environmental impacts and enhancing positive impacts; and includes the process of mitigating and managing adverse environmental impacts throughout project implementation. IFC favors preventive measures over mitigatory or compensatory measures, whenever feasible.

3. EA takes into account the natural environment (air, water, and land); human health and safety; and social aspects (involuntary resettlement, indigenous peoples and cultural property);[3] and transboundary and global environmental aspects[4]. EA considers natural and social aspects in an integrated way. It also takes into account the variations in project and country conditions; the findings of country environmental studies; national environmental action plans; the country's overall policy framework and national legislation; the project sponsor's capabilities related to the environment and social aspects, and obligations of the country, pertaining to project activities, under relevant international environmental treaties and

agreements. IFC does not finance project activities that would contravene such country obligations, as identified during the EA. EA is initiated as early as possible in project processing and is integrated closely with the economic, financial, institutional, social, and technical analyses of a proposed project.

4. The project sponsor is responsible for carrying out the EA. For Category A projects[5] the project sponsor retains independent EA experts not affiliated with the project to carry out the EA.[6] For Category A projects that are highly risky or contentious or that involve serious and multidimensional environmental concerns, the project sponsor should normally also engage an advisory panel of independent, internationally recognized environmental specialists to advise on all aspects of the project relevant to the EA.[7] The role of the advisory panel depends on the degree to which project preparation has progressed, and on the extent and quality of any EA work completed, at the time IFC begins to consider the project.

5. IFC advises the project sponsor on IFC's EA requirements. IFC reviews the findings and recommendations of the EA to determine whether they provide an adequate basis for processing the project for IFC financing. When the project sponsor has completed or partially completed EA work prior to IFC's involvement in a project, IFC reviews the EA to ensure its consistency with this policy. IFC may, if appropriate, require additional EA work, including public consultation and disclosure.

6. The *Pollution Prevention and Abatement Handbook* describes pollution prevention and abatement measures and emission levels that are normally acceptable to IFC. However, taking into account country legislation and local conditions, the EA may recommend alternative emission levels and approaches to pollution prevention and abatement for the project. The EA report must provide full and detailed justification for the levels and approaches chosen for the particular project or site.

EA Instruments

7. Depending on the project, a range of instruments can be used to satisfy IFC's EA requirement: environmental impact assessment (EIA), environmental audit, hazard or risk assessment, and environmental action plan (EAP).[8] EA applies one or more of these instruments, or elements of them, as appropriate.

Environmental Screening

8. IFC undertakes environmental screening of each proposed operation to determine the appropriate extent and type of EA. IFC classifies the proposed project into one of four categories, depending on the type, location, sensitivity, and scale of the project and the nature and magnitude of its potential environmental impacts.

(a) *Category A*: A proposed project is classified as Category A if it is likely to have significant adverse environmental impacts that are sensitive,[9] diverse, or unprecedented. These impacts may affect an area broader than the sites or facilities subject to physical works. EA for a Category A project examines the project's potential negative and positive environmental impacts, compares them with those of feasible alternatives (including, the "without project" situation), and recommends any measures needed to prevent, minimize, mitigate, or compensate for adverse impacts and improve environmental performance. For a Category A project, the project sponsor is responsible for preparing a report, normally an EIA that includes, as necessary, elements of the other instruments referred to in para 7.

(b) *Category B* : A proposed project is classified as Category B if its potential adverse environmental impacts on human populations or environmentally important areas—including wetlands, forests, grasslands, and other natural habitats—are less adverse than those of Category A projects. These impacts are site-specific; few if any of them are irreversible; and in most cases mitigatory measures can be designed more readily than for Category A projects. The scope of EA for a Category B project may vary from project to project, but it is narrower than that of Category A EA. Like Category A EA, it examines the project's potential negative and positive environmental impacts and recommends any measures needed to prevent, minimize, mitigate, or compensate for adverse impacts and improve environmental performance. The findings and results of Category B EA are described in the Environmental Review Summary, which is prepared by IFC [10]

(c) *Category C:* A proposed project is classified as Category C if it is likely to have minimal or no adverse environmental impacts.

Beyond screening, no further EA action is required for a Category C project.

(d) *Category FI*: A proposed project is classified as Category FI if it involves investment of IFC funds through a financial intermediary, in subprojects that may result in adverse environmental impacts. In addition, in some capital markets projects, IFC funds are not targeted to specific subprojects (e.g. equity in a financial institution such as a commercial bank), but the financial institution has operations which may have adverse environmental impacts (e.g. project finance). In such cases, IFC may also classify the project as Category FI.

EA for Special Project Types

Financial Intermediary Lending

9. For a financial intermediary (FI) operation targeting specific subprojects, IFC requires that each FI screen proposed subprojects and ensure that subproject sponsors carry out appropriate EA for each subproject. Before approving a subproject, the FI verifies (through its own staff, outside experts, or existing environmental institutions) that the subproject meets the environmental requirements of appropriate national and local authorities and is consistent with this OP and other applicable environmental policies of IFC.[11] When IFC funds are not targeted to specific subprojects (e.g. equity in a financial institution such as a commercial bank) but the financial institution has operations which may have adverse environmental impacts, IFC will require the FI to receive training on environmental management, if necessary. In addition, IFC requires that investments under the relevant operations comply with host country environmental, health and safety requirements; no further environmental requirements would normally be applied to these operations.

10. In appraising a proposed FI investment by IFC, IFC reviews the adequacy of the proposed FI's EA arrangements for subprojects, including the mechanisms and responsibilities for environmental screening and review of EA results. When necessary, IFC ensures that the project includes components to strengthen such EA arrangements. For FI operations expected to have Category A subprojects, during appraisal IFC examines the FI's institutional capacity for its subproject EA work and identifies, as necessary, measures to strengthen capacity. If IFC is not satisfied that adequate capacity exists for carrying out EA, all Category A subprojects and, as appropriate, Category B subprojects—including EA reports—are subject to prior review and approval by IFC.[12]

Institutional Capacity

11. When the project sponsor has inadequate environmental capacity to carry out key EA-related functions (such as review of EA, environmental monitoring, inspections, or management of mitigation measures) for a proposed project, IFC requires the project sponsor to strengthen internal staff capacity or retain qualified outside expertise.

Public Consultation

12. For all Category A projects and as appropriate for Category B projects during the EA process, the project sponsor consults project-affected groups and local nongovernmental organizations (NGOs) about the project's environmental aspects and takes their views into account. The project sponsor initiates such consultations as early as possible. For Category A projects, the project sponsor consults these groups at least twice: (a) shortly after environmental screening and before the terms of reference for the EA are finalized, and (b) once a draft EA report is prepared. In addition, the project sponsor consults with such groups throughout project implementation, as necessary to address EA related issues that affect them.[13]

13. In those cases where the Category A EA has been completed prior to IFC involvement in a project, IFC reviews the public consultation and disclosure carried out by the project sponsor during and after EA preparation. If necessary IFC and the project sponsor then agree on a supplemental public consultation and disclosure program to address any deficiencies identified by IFC. On completion of the supplemental program the project sponsor prepares a report detailing the results of the full public consultation and disclosure program. The Category A EA will only be made available to the World Bank's InfoShop once this report is complete.

Disclosure

14. For meaningful consultations between the project sponsor and project-affected groups and local NGOs on all Category A and as appropriate for Category B projects, the project sponsor provides relevant material in a timely manner prior to consultation and in a form and language that are understandable and accessible to the groups being consulted.

15. For a Category A project, the project sponsor provides for the initial consultation a summary of the proposed project's objectives, description, and potential impacts; for consultation after the draft EA report is prepared, the project sponsor provides a summary of the EA's conclusions. In addition, for a Category A project, the project sponsor makes the draft EA report available at a public place accessible to project-affected groups and local NGOs. For FI operations, the FI ensures that EA reports for Category A subprojects are made available in a public place accessible to affected groups and local NGOs.

16. The Category B report (Environmental Review Summary) for a project is made available to project affected groups and local NGOs.

17. Once the project sponsor officially provides a Category A EA report to IFC, IFC distributes the summary (in English) to the members of IFC's Board of Directors. As required under its policy on disclosure, IFC also makes the Category A EA and Category B environmental information available through the World Bank InfoShop.[14] If the project sponsor objects to IFC's releasing this environmental information through the World Bank InfoShop, IFC staff do not continue work on the project. In rare and compelling circumstances and for Category B projects only, an exception to the time deadline associated with this public disclosure requirement may be granted in writing by the Vice President, Investment Operations.

Implementation

18. During project implementation, the project sponsor reports on compliance with (a) measures agreed with IFC on the basis of the findings and results of the EA, including implementation of any EAP, as set out in the project documents; (b) the status of mitigatory measures; and (c) the findings of monitoring programs. IFC bases supervision of the project's environmental aspects on the findings and recommendations of the EA, including measures set out in the legal agreements, any EAP, and other project documents.

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1. The International Finance Corporation (IFC) is the World Bank Group entity with a mandate to invest in private sector projects in developing member countries. It lends directly to and makes equity investments in private companies without guarantees from governments, and attracts other sources of funds for these projects. IFC also provides advisory services and technical assistance to governments and businesses. This policy also covers projects funded under the Global Environment Facility (GEF)."EA" refers to the entire process set out in OP 4.01

2. For definitions, see Annex A. The area of influence for any project is determined with the advice of environmental specialists and set out in the EA terms of reference.

3. See OP 4.12, *Involuntary Resettlement*, and OP 4.10, *Indigenous Peoples* (forthcoming); OD 4.20, *Indigenous Peoples*; and OP 4.11, *Safeguarding Cultural Property in IFC-Financed Projects* (forthcoming).

4. Global environmental issues include climate change, ozone-depleting substances, pollution of international waters, and adverse impacts on biodiversity.

5. For screening, see para. 8.

6. EA is closely integrated with the project's economic, financial, institutional, social, and technical analyses to ensure that (a) environmental considerations are given adequate weight in project selection, siting, and design decisions; and (b) EA does not delay project processing. However, the project sponsor ensures that when individuals or entities are engaged to carry out EA activities, any conflict of interest is avoided. For example, when an independent EA is required, it is not carried out by the consultants hired to prepare the engineering design.

7. The panel (which is different from the dam safety panel required under OP 4.37, *Safety of Dams*) advises the project sponsor specifically on the following aspects: (a) the terms of reference for the EA, (b) key issues and methods for preparing the EA, (c) recommendations and findings of the EA, (d) implementation of the EA's recommendations, and (e) development of environmental management capacity.

8. These terms are defined in Annex A. Annexes B and C discuss the content of EA reports and EAPs.

9. A potential impact is considered "sensitive" if it may be irreversible (e.g., lead to loss of a major natural habitat) or raise issues covered by OP 4.10, *Indigenous Peoples (forthcoming)* ; OP 4.04, *Natural Habitats*; OP 4.11, *Safeguarding Cultural Property* in IFC-Financed Projects (forthcoming); or OP 4.12, *Involuntary Resettlement*.

10. When the screening process determines, or national legislation requires, that any of the environmental issues identified warrant special attention, the findings and results of the Category B EA may be set out in a separate report. Depending on the type of project and the nature and magnitude of the impacts, this report may include, for example, a limited environmental impact assessment, an environmental mitigation or action plan, an environmental audit, or a hazard assessment. For Category B projects that are not in environmentally sensitive areas and that present well-defined and well-understood issues of narrow scope, IFC may accept alternative approaches for meeting EA requirements: for example, environmentally sound design criteria, siting criteria, or pollution standards for small-scale industrial plants or rural works; environmentally sound siting criteria, construction standards, or inspection procedures for housing projects; or environmentally sound operating procedures for road rehabilitation projects.

11. The requirements for FI operations are derived from the EA process, and are consistent with the provisions of para 6 of this OP. The EA process takes into account the type of finance being considered, the nature and scale of anticipated subprojects, and the environmental requirements of the jurisdiction in which subprojects will be located.

12. The criteria for prior review of Category B subprojects, which are based on such factors as type or size of the subproject and the EA capacity of the financial intermediary, are set out in the legal agreements for the project.

13. For projects with major social components, consultations are also required by other IFC policies—for example OP 4.10, *Indigenous Peoples (forthcoming)*, and OP 4.12, *Involuntary Resettlement.*

14. For a further discussion of IFC's disclosure procedures, see *IFC's Policy on Disclosure of Information.* Specific requirements for disclosure of resettlement plans and indigenous peoples development plans are set out in OP 4.12, *Involuntary Resettlement* (forthcoming), and OP 4.10, *Indigenous Peoples* (forthcoming).

Annex A

Definitions

1. *Environmental audit*: An instrument to determine the nature and extent of all environmental areas of concern at an existing facility. The audit identifies and justifies appropriate measures to mitigate the areas of concern, estimates the cost of the measures, and recommends a schedule for implementing them. For certain projects, the EA report may consist of an environmental audit alone; in other cases, the audit is part of the EA documentation.

2. *Environmental impact assessment (EIA)*: An instrument to identify and assess the potential environmental impacts of a proposed project, evaluate alternatives, and design appropriate mitigation, management, and monitoring measures.

3. *Environmental action plan: (EAP)* An instrument that details (a) the measures to be taken during the implementation and operation of a project to eliminate or offset adverse environmental impacts, or to reduce them to acceptable levels; and (b) the actions needed to implement these measures. The EAP is an integral part of Category A EAs (irrespective of other instruments used). EAs for Category B projects may also result in an EAP.

4. *Hazard assessment*: An instrument for identifying, analyzing, and controlling hazards associated with the presence of dangerous materials and conditions at an installation. IFC requires a hazard assessment for projects involving certain inflammable, explosive, reactive, and toxic materials when they are present at a site in quantities above a specified threshold level. For certain projects, the EA report may consist of the hazard assessment alone; in other cases, the hazard assessment is part of the EA documentation.

5. *Project area of influence* : The area likely to be affected by the project, including all its ancillary aspects, such as power transmission corridors, pipelines, canals, tunnels, relocation and access roads, borrow and disposal areas, and construction camps, as well as unplanned developments induced by the project (e.g., spontaneous settlement, logging, or shifting agriculture along access roads). The area of influence may include, for example, (i) the watershed within which the project is located; (ii) any affected estuary and coastal zone; (iii) off-site areas required for resettlement or compensatory tracts; (iv) the airshed (e.g., where airborne pollution such as smoke or dust may enter or leave the area of influence); (v) migratory routes of humans, wildlife, or fish, particularly where they relate to public health, economic activities, or environmental conservation; and (vi) areas used for livelihood activities (hunting, fishing, grazing, gathering, agriculture, etc.) or religious or ceremonial purposes of a customary nature.

6. *Risk assessment*: An instrument for estimating the probability of harm occurring from the presence of dangerous conditions or materials at an installation. Risk represents the likelihood and significance of a potential hazard being realized; therefore, a hazard assessment often precedes a risk assessment, or the two are conducted as one exercise. Risk assessment is a flexible method of analysis; a systematic approach to organizing and analyzing information about potentially hazardous activities or about substances that might pose risks under specified conditions. IFC routinely requires risk assessment for projects involving handling, storage,

or disposal of hazardous materials and waste; the construction of dams; or major construction works in locations vulnerable to seismic activity or other potentially damaging natural events. For certain projects, the EA report may consist of the risk assessment alone; in other cases, the risk assessment is part of the EA documentation.

Annex B

Content of an Environmental Assessment Report for a Category A Project

1. An environmental assessment (EA) report for a Category A project[1] focuses on the significant environmental issues of a project. The report's scope and level of detail should be commensurate with the project's potential impacts. The report submitted to IFC is prepared in English, French, or Spanish, and the executive summary in English.

2. The EA report should include the following items (not necessarily in the order shown):

(a) *Executive summary*. Concisely discusses significant findings and recommended actions.

(b) *Policy, legal, and administrative framework*. Discusses the policy, legal, and administrative framework within which the EA is carried out. Explains the environmental requirements of any cofinanciers. Identifies relevant international environmental agreements to which the country is a party.

(c) *Project description* . Concisely describes the proposed project and its geographic, ecological, social, and temporal context, including any off-site investments that may be required (e.g., dedicated pipelines, access roads, power plants, water supply, housing, and raw material and product storage facilities). Indicates the need for any resettlement plan or indigenous peoples development plan[2] (see also subpara (h)(v) below). Normally includes a map showing the project site and the project's area of influence.

(d) *Baseline data* . Assesses the dimensions of the study area and describes relevant physical, biological, and socioeconomic conditions, including any changes anticipated before the project commences. Also takes into account current and proposed development activities within the project area but not directly connected to the project. Data should be relevant to decisions about project location, design, operation, or mitigatory measures. The section indicates the accuracy, reliability, and sources of the data.

(e) *Environmental impacts* . Predicts and assesses the project's likely positive and negative impacts, in quantitative terms to the extent possible. Identifies mitigation measures and any residual negative impacts that cannot be mitigated. Explores opportunities for environmental enhancement. Identifies and estimates the extent and quality of available data, key data gaps, and uncertainties associated with predictions, and specifies topics that do not require further attention.

(f) *Analysis of alternatives*.[3] Systematically compares feasible alternatives to the proposed project site, technology, design, and operation—including, the “without project” situation—in terms of their potential environmental impacts; the feasibility of mitigating these impacts; their capital and recurrent costs; their suitability under local conditions; and their institutional, training, and monitoring requirements. For each of the alternatives, quantifies the environmental impacts to the extent possible, and attaches economic values where feasible. States the basis for selecting the particular project design proposed and justifies recommended emission levels and approaches to pollution prevention and abatement.

(g) *Environmental action plan (EAP)* . Covers mitigation measures, monitoring, and institutional strengthening; see outline in OP 4.01, Annex C.

(h) *Appendixes*

(i) List of EA report preparers—individuals and organizations.

(ii) References—written materials, both published and unpublished, used in study preparation.

(iii) Record of interagency and consultation meetings, including consultations for obtaining the informed views of the affected people and local nongovernmental organizations (NGOs). The record specifies any means other than consultations (e.g., surveys) that were used to obtain the views of affected groups and local NGOs.

(iv) Tables presenting the relevant data referred to or summarized in the main text.

(v) List of associated reports (e.g., resettlement plan or indigenous peoples development plan).

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1. The EA report for a Category A project is normally an environmental impact assessment, with elements of other instruments included as appropriate. Any report for a Category A operation uses the components described in this annex. IFC's Environment and Social Development Department can provide detailed guidance on the focus and components of the various EA instruments.

2. See OP 4.12, *Involuntary Resettlement* and OP 4.10, *Indigenous Peoples* (forthcoming).

3. EIA is normally best suited to the analysis of alternatives within a given project concept (e.g., a geothermal power plant, or a project aimed at meeting local energy demand), including detailed site, technology, design, and operational alternatives. Where a project has broad environmental implications (e.g. a large reservoir), these should be addressed through a careful and comprehensive analysis of the project's area of influence and the proper scoping of the EIA.

Annex C

Environmental Action Plan

1. A project's environmental action plan (EAP) consists of the set of mitigation, management, monitoring, and institutional measures to be taken during implementation and operation to eliminate adverse environmental and social impacts, offset them, or reduce them to acceptable levels. The plan also includes the actions needed to implement these measures.[1] Action plans are essential elements of EA reports for Category A projects; for many Category B projects, the EA may result in an action plan only. To prepare an action plan, project sponsors and their EA design team (a) identify the set of responses to potentially adverse impacts; (b) determine requirements for ensuring that those responses are made effectively and in a timely manner; and (c) describe the means for meeting those requirements.[2] More specifically, the EAP includes the following components.

Mitigation

2. The EAP identifies feasible and cost-effective measures that may reduce potentially significant adverse environmental impacts to acceptable levels. The plan includes compensatory measures if mitigation measures are not feasible, cost-effective, or sufficient. Specifically, the EAP

(a) identifies and summarizes all anticipated significant adverse environmental impacts (including those involving indigenous people or involuntary resettlement);

(b) describes—with technical details—each mitigation measure, including the type of impact to which it relates and the conditions under which it is required (e.g., continuously or in the event of contingencies), together with designs, equipment descriptions, and operating procedures, as appropriate;

(c) estimates any potential environmental impacts of these measures; and

(d) provides linkage with any other mitigation plans (e.g., for involuntary resettlement or indigenous peoples) required for the project.

Monitoring

3. Environmental monitoring during project implementation provides information about key environmental aspects of the project, particularly the environmental impacts of the project and the effectiveness of mitigation measures. Such information enables the project sponsor and IFC to evaluate the success of mitigation as part of project supervision, and allows corrective action to be taken when needed. Therefore, the EAP identifies monitoring objectives and specifies the type of monitoring, with linkages to the impacts assessed in the EA report and the mitigation measures described in the EAP. Specifically, the monitoring section of the EAP provides

(a) a specific description, and technical details, of monitoring measures, including the parameters to be measured, methods to be used, sampling locations, frequency of measurements, detection limits (where appropriate), and definition of thresholds that will signal the need for corrective actions; and

(b) monitoring and reporting procedures to (i) ensure early detection of conditions that necessitate particular mitigation measures, and (ii) furnish information on the progress and results of mitigation.

Capacity Development and Training

4. To support timely and effective implementation of environmental project components and mitigation measures, the EAP draws on the EA's assessment of the existence, role, and capability of environmental units on site.[3] If necessary, the EAP recommends the establishment or expansion of such units, and the training of staff, to allow implementation of EA recommendations. Specifically, the EAP provides a specific description of the project sponsor's arrangements—who is responsible for carrying out the mitigatory and monitoring measures (e.g., for operation, supervision, monitoring of implementation, remedial action, financing, reporting, and staff training). To strengthen the project sponsor's environmental management capability, most EAPs cover one or more of the following additional topics: (a) technical assistance programs, (b) procurement of equipment and supplies, and (c) organizational changes.

Implementation Schedule and Cost Estimates

5. For all three aspects (mitigation, monitoring, and capacity development), the EAP provides (a) an implementation schedule for measures that must be carried out as part of the project, showing phasing and coordination with overall project implementation plans; and (b) the capital and recurrent cost estimates and sources of funds for implementing the EAP.

Integration of EAP with Project

6. The project sponsor's decision to proceed with a project, and IFC's decision to support it, are predicated in part on the expectation that the EAP will be executed effectively. Consequently, IFC expects the plan to be specific in its description of the individual mitigation, management and monitoring measures and its assignment of responsibilities, and it must be integrated into the project's overall planning, design, budget, and implementation. Such integration is achieved by establishing the EAP within the project so that the plan will receive funding and supervision along with the other components.

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1. The action plan is sometimes known as a "management plan."

2. For projects involving rehabilitation, upgrading, expansion, or privatization of existing facilities, remediation of existing environmental problems may be more important than mitigation and monitoring of expected impacts. For such projects, the action plan focuses on cost-effective measures to remediate and manage these problems.

3. For projects having significant environmental implications, it is particularly important that the project sponsor have an in-house environmental unit with adequate budget and professional staffing strong in expertise relevant to the project.

Consultation Comments

1. This policy allows IFC to waive certain environmental standards on emission levels or approaches to pollution prevention and abatement (see paragraph 6, OP 4.01). Even when waivers must be justified, this omnibus clause seems to undercut Bank policies almost arbitrarily and should be deleted. If waivers are required, IFC should seek specific Board approval. Another viewpoint finds the new Handbook to be more flexible, reflecting more holistic conceptual thinking, and expressing an ecosystem approach. IFC's demand-driven, single-project focus, however, means that to operationalize this more comprehensive approach, IFC must work closely with the Bank at project and sectoral levels.

OP 4.01, *Environmental Assessment* reflects, and is consistent with, the *Pollution Prevention and Abatement Handbook*. The *Handbook* states that: "New projects should meet the *maximum emission levels* contained in the sector-specific guidelines unless the site-specific environmental analysis (which the Bank Group requires for all projects that may affect the environment and which takes into account local conditions and national legislation) recommends stricter controls or provides a justification for a variance from the guidelines contained in the *Handbook*." Depending on host country laws and regulations and local conditions, for example, the EA may result in recommendations for different requirements than specified in the *Handbook* . In such cases the recommended variance must be fully justified in the EA and any variance will only be acceptable if both IFC and the project sponsor agree on the variance. IFC has established a procedure that any variance from the *Handbook* requirements is approved by IFC's Vice President, Investment Operations. IFC expects that a variance allowing the use of lesser standards than those contained in the *Handbook* will be permitted only in rare and compelling circumstances.

2. IFC projects should engender a sense of ownership in those populations and communities they seek to benefit and the emphasis should be on using local technology, resources, skills and standards wherever possible.

IFC agrees that locally affected people and communities should be informed about proposed projects and be consulted about a project's positive and negative impacts and mitigation measures. This allows project affected people and interested parties to submit informed feedback to project sponsors and financiers. IFC has written and published a *Good Practice Manual* (October 1998*)* as a "how to" guide for project sponsors in implementing public consultation and disclosure activities. The *Manual* includes a discussion on the use of local resources and training of the local workforce to help foster community development in the project affected area.

3. Where applicable, the EA report should include the resettlement plan and the indigenous people's development plan.

Resettlement plans and indigenous peoples action plans, where required, are considered substantive EA addenda. For Category A projects, the revised environmental and social review procedure (ESRP) requires that all substantive addenda be disclosed and consulted on similarly to the requirements for the Category A EA report.

4. The addition of an independent panel of experts for Category A projects (OP 4.01, paragraph 4) is welcome, but the fact that it is the sponsor's duty to set it up could undermine its independence. IFC should make the Panel's recommendations mandatory, and not just advisory.

The Independent Panel of Experts is advisory to the project sponsor. The Panel begins at the front end of the EA process and continues through project implementation with the aim of bringing international best practice to the project. While the Panel is retained by the project sponsor it retains its independence from the project sponsor because members are experts with international reputations to uphold. To ensure an interactive process, IFC will review the recommendations of the Independent Panel both with Panel members and the project sponsor.

5. IFC should include in OP 4.01 an assessment of cumulative and associated impacts, as is common practice in the US.

Assessment of cumulative impacts normally is oriented to regional or sectoral concerns, reflected in the World Bank version of OP 4.01, *Environmental Assessment*. IFC has recognized that there may be some projects that IFC is considering where it is appropriate to have the project sponsor include consideration of cumulative impacts. IFC therefore has included in the IFC environmental and social review procedure (ESRP) language that reflects this: "The EA involves consideration of the following, as appropriate to specific projects, cumulative impacts of existing projects, the proposed project, and anticipated future projects" and "Project specific EIA reports should normally cover … potential environmental and social impacts (direct and indirect), including opportunities for enhancement; this includes the cumulative impact of the proposed project and other developments which are anticipated". IFC has added a footnote to the ESRP noting "The assessment of cumulative impacts would take into account projects or potential developments that are realistically defined and described at the time the EA is undertaken and where they would directly impact on the project area."

6. Paragraphs 3 and 12 of OP 4.01 speak of the need to assess national environmental action plans and national legislation. The IFC environmental assessment process should clearly identify national legal requirements, and IFC projects should be judged in part by their compliance with applicable national environmental laws and regulations.

In Paragraph 3 of OP 4.01, the EA process clearly states that "EA considers natural and social aspects in an integrated way. It also takes into account the variations in project and country conditions; the findings of country environmental studies; national environmental action plans; the country's overall policy framework and national legislation; the project country's overall policy framework and national legislation, the project sponsor's capabilities related to the environment, and obligations of the country, pertaining to project activities, under relevant international environmental treaties and agreements. IFC does not finance project activities that would contravene such country obligations, as identified during the EA." The EA process, as laid out in IFC's OP 4.01 therefore requires a clear identification of national legal requirements related to the environment. IFC's environmental and social review procedure (ESRP) requires the project sponsor to ensure compliance with host country requirements. Investment agreements also contain covenants requiring the project sponsor to comply with IFC and host country requirements.

7. In OP 4.01, paragraph 11, the discussion of financial intermediaries, non-targeted funds requires clarification. It says, "IFC may…require that investments…comply with host country requirements." Under what circumstances would compliance with host country requirements not be mandated?

This implication resulted from a grammatical construct and was not the intent. The language has been changed to "…IFC will require the FI to receive training, if necessary. In addition, IFC requires that investments… comply with host country environmental, health and safety requirements..."

Appendix D Proposed Questionnaire on Existing Power System

WINSYS QUESTIONNAIRE[1]

Table 1 System identification data.

System	
Status year	
Annual load ex. desalination (MWh)	
Annual desalination demand (m^3)	

Table 2 Conventional generating capacity.

	G1	G2	G3		
Site					
Type specification					
Installed cap.[1] (kW)					
Commissioned (year)					
Lifetime (year)					
Fuel type					
Full load efficiency (%)					
Min load efficiency (%)					
Tech. min load (%)					
Tech. availability (%)					
Investment (ECU/kW)					
Non fuel O&M (ECU/h)					
Start/stop (ECU/#)					
[1] $\cos(\varphi) = 0.8$					

Table 3 Fuel specification.

Type					
Heat value (kWh/kg)					
Cost (ECU/kg)					

Table 4 Misc. forecasts and plans.

Load forecasts	
Conventional capacity expansion	
Desalination demand forecasts	
Fuel costs forecasts	

Table 5 Wind data (air port, met.-mast, etc.)

Wind data time series (wind speed, direction)	
Met. mast anemometer height (m)	
Met. mast site description (map etc.)	
Annual avg. temperature (deg. C)	
Annual avg. air pressure (mBar)	

[1] See reference (J.C.Hansen & J.O.G.Tande, 1994)

Table 1 Desalination capacity (optional).

Desalination plant type	
Capacity (m^3/day)	
Electric full load (kW)	

Table 2 Load specification.

	Jan-Mar		Apr-Jun		Jul-Sep		Oct-Dec	
Hour of day	Week-day (MW)	Week-end (MW)	Week-day (MW)	Week-end (MW)	Week-day (MW)	Week-end (MW)	Week-day (MW)	Week-end (MW)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								

Table 8 Water demand specification (optional).

Hour of day	Jan-Mar (m^3)	Apr-Jun (m^3)	Jul-Sep (m^3)	Oct-Dec (m^3)
1				
2				
3				
4				
5				
6				
7				
8				
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Abstract (max. 2000 characters)

The overall objective of this research project is to study the development of methods and guidelines rather than "universal solutions" for the use of wind energy in isolated communities. So far most studies of isolated systems with wind power have been case-oriented and it has proven difficult to extend results from one project to another, not least due to the strong individuality that has characterised such systems in design and implementation.

In the present report a unified and generally applicable approach is attempted in order to support a fair assessment of the technical and economical feasibility of isolated power supply systems with wind energy.

General guidelines and checklists on which facts and data are needed to carry out a project feasibility analysis are presented as well as guidelines how to carry out the project feasibility study and the environmental analysis.

The report outlines the results of the project as a set of proposed guidelines to be applied when developing a project containing an application of wind in an isolated power system. It is the author's hope that this will facilitate the development of projects and enhance electrification of small rural communities in developing countries.

Descriptors INIS/EDB

DIESEL ENGINES; DISPERSED STORAGE AND GENERATION; FEASIBILITY STUDIES; ON-SITE POWER GENERATION; POWER SYSTEMS; RECOMMENDATIONS; REMOTE AREAS; RURAL AREAS; WIND POWER

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