

**WIND POWER PROJECTS IN THE CDM:
METHODOLOGIES AND TOOLS FOR
BASELINES, CARBON FINANCING AND
SUSTAINABILITY ANALYSIS**

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EXECUTIVE SUMMARY

1.1 Background

The Clean Development Mechanism (CDM) may stimulate considerable investments by industrialized countries in wind power and other renewable energy technologies reducing greenhouse gas (GHG) emissions in developing countries. The CDM is a global mechanism under the Kyoto Protocol that enables investors to receive credit toward their own greenhouse gas emission reduction obligations. Emission reductions may also be traded in the emerging global carbon offsets market.

In order to produce satisfactory and credible emission reductions, it must be demonstrated convincingly that CDM projects would bring down emissions per unit of output (measured in tonne of CO₂ equivalents per MWh) to a level below that which according to the baseline scenario would have existed in the absence of the CDM project. The amount of GHG emission reductions generated by a CDM project is the difference between the GHGs per unit of energy output, i.e. the emission factor, in the baseline scenario multiplied by the CDM project's energy production and the amount of emissions from the CDM project's energy production (considered insignificant in most cases). The emission reductions generated by a CDM project are thus the amount of GHG emissions that is avoided by implementing a renewable energy alternative that displaces electricity generation from power plants that are built and operated under business-as-usual conditions and are fueled either by coal, oil, or natural gas.

Wind power may become a major source of renewable, climate-friendly energy in developing countries. The capital costs and the competitiveness of electricity generation alternatives will strongly shape investments in renewable energy technologies in developing countries over the coming decades. The income earned by selling GHG emission reductions will increase the total income to an investor from a project and will improve the competitiveness of wind power against conventional power generators in an increasingly competitive market. But whether the CDM will accelerate the penetration of wind power in the developing world will strongly depend upon the balance of the wind energy costs and the GHG offsets price compared to the capital costs of electricity generation alternatives.

This report is intended to be a guidance document for project developers, investors, lenders, and CDM host countries involved in wind power projects in the CDM. The report explores in particular those issues that are important in the assessment and development of a CDM project—that is, baseline development, carbon financing, and environmental sustainability. It does not deal in detail with those issues that are routinely covered in a standard wind power project assessment. The report tests, compares, and recommends methodologies for, and approaches to, baseline development, carbon financing analysis, social costing, and environmental sustainability analysis. In order to present and explore the application and implications of the various methodologies and approaches in a concrete context, Africa's largest wind farm—namely the 60 MW wind farm located in Zafarana, Egypt—is examined as a hypothetical CDM wind power project.

Detailed practical analytical experience with baseline development is still quite recent. Most of the existing experience comes from demonstration and trial projects undertaken in the context of the Activities Implemented Jointly (AIJ) Pilot Phase in which emission reductions maximization

and cost minimization have been secondary objectives only.¹ But the CDM, when it enters into force, is bound to increase the pressure on the development of low-cost, practical, and accurate baseline methodologies.

1.2 Implications of Baseline Methodologies in the Marrakesh Accords

The Marrakesh Accords, which were agreed to in 2001 in Morocco, define three standardized approaches to baseline development as follows:

- (a) “Existing actual or historical emissions, as applicable; or
- (b) Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment; or
- (c) The average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 per cent of their category.”²

The report explores and compares the standardized, multi-project approaches and the project-specific approach to baseline development outlined in this key international agreement. Seven standardized, multi-project baselines are established, and it is shown that there is a difference of about 25% between the highest emission rate (0.6868 tCO₂/MWh) and the lowest emission rate (0.5496 tCO₂/MWh) estimated in accordance with the three standardized baseline approaches. This difference in emission factors is to some extent a result of including hydroelectric power in the baseline scenario. Hydroelectric resources constitute around 21% of the generation capacity in Egypt and, if hydropower is excluded from the baseline, the difference between the highest and the lowest baseline is reduced to 18%. Furthermore, since the two variations of the “historical” baseline option examined in the report result in the highest and the lowest baselines, the difference is reduced to 16% if this approach is disregarded altogether.

The ES³-model, which the Systems Analysis Department at Risø National Laboratory has developed, enables the report to explore the project-specific approach to baseline development in some detail. Using relatively disaggregated data on the Egyptian electricity system, including the wind power production profile of Zafarana, the emission rates estimated by runs of the simulation tool ES³ range from 0.610 tCO₂/MWh to 0.590 tCO₂/MWh. Interestingly, these results are very similar to the estimates based on two different interpretations of option (c) above, namely the “last five years of additions/all fuels” option (0.5936 tCO₂/MWh) and the “last five years of additions/LFO/NG” option (0.583 tCO₂/MWh).

Great care should be taken in generalizing these results to other countries, electricity grids, and electric power sectors. The results for the Egyptian electric power sector have primarily illustrative value. The reason is that the structure of electricity grids and electricity sectors often varies significantly from country to country, and that the baseline level will reflect the specific circumstances of each individual case. Thus, the same baseline methodology would give different results in terms of quantities of emission reductions in countries with dissimilar electricity sectors. Also important, however, different baseline methodologies for the electricity sector may

¹ Projects developed during under the AIJ Pilot Phase, which was initiated in 1995, are not eligible for crediting under the Kyoto Protocol. These projects have primarily served as vehicles for learning-by-doing and experimentation. See <http://unfccc.int/issues/aij.html>.

² “*Report of the Conference of the Parties on Its Seventh Session, Held at Marrakesh from 29 October to 10 November 2001*,” (21 January 2002), FCCC/CP/2001/13/Add.2, p. 21.

in some cases give quite similar results. This report, as shown above, also presents examples of this outcome.

1.2.1 Which Baseline Methodology is Preferable?

It is expectable that both investors and host countries would choose the baseline methodology that gives the highest emission rate and results in the largest offsets revenue earnings. But project developers should also consider other issues when choosing among different eligible baseline methodologies. Some key issues to take into account are the following:

- Ease of operationalization;
- Computational complexity;
- Ability to take into account specific circumstances;
- Future refinement;
- Flexibility; and
- Ease of monitoring and verification.

All these issues are important, but they might not be easily combined. For instance, it may be difficult for a baseline methodology to address at the same time the issue of operationalizability and the issue of the ability to take into account specific circumstances of individual countries. It is also very important to take into account the transaction costs—they will vary across the above list of issues—as well as the consistency with internationally approved and agreed rules for baseline development under the CDM.

The most costly baseline methodology or approach explored in this study, namely the project-specific assessment based on the ES³-model simulations, does not give an emission factor and a baseline that is more attractive in terms of amount of emission reductions generated. In addition to the detailed data and the longer time needed for model development, issues regarding the transparency and replicability of the baseline may be raised in regard to the simulation approach. At the same time, some of the standardized baseline approaches outlined in the Marrakesh Accords seem unable to produce a reasonably accurate baseline for the electric power sector.

The baseline methods and methodologies defined in the Marrakesh Accords are currently being tested and further refined in a number of studies and projects. Alternative baseline methodologies are also under development, and so are combinations of methodologies, such as the combined margin approach.³ The combined margin approach takes into account the effects of a new project on emissions from (1) the operation of current and future power plants (referred to as the operating margin) and (2) on whether and when new power plants would be built (referred to as the built margin).⁴ The analysis presented in chapter 5 focuses on Zafarana's impact on the dispatch, or operation, of existing and future generation plants in Egypt, whereas the "economic attractive course of action" option and the "similar projects undertaken in the previous five years" option examined in chapter 4 could serve as proxy build margin approaches.

1.3 Carbon Financing

It is financially beneficial for the Zafarana project to pursue the "CDM route" in all the pricing and baseline cases examined in this report. For the best baseline, the project's return on equity is

³ S. Kartha, M. Lazarus, and M. Bosi, *Practical Baseline Recommendations for Greenhouse Gas Mitigation Projects in the Electric Power Sector* (IEA, Paris: OECD and IEA Information Paper, 2002).

⁴ This approach was recently tested in Brazil, Chile, and South Africa (Bosi et al., 2002).

increased by between 2.26% (CER at \$2) and 9.9% (CER at \$10). This conclusion bears out the conclusion of the “quick scan” assessment presented in the report, namely that turning a conventional wind energy project of the size and scope of the Zafarana wind farm into a CDM project would definitely be beneficial to the investor. The CDM’s impact on a project’s finances depends both on the baseline and on the offset price, and developers should attempt to maximize both variables.

It is important to notice that CER revenues alone would not be sufficient to make a non-viable project financially viable. But the CER revenues could turn a marginally viable project into a project with more attractive returns and raise the project in an investor’s ranking of possible investments, thus increasing the likelihood of investment being secured and the wind park being constructed. However, the particular context of the Zafarana wind farm must be kept in mind. Other wind power projects might have different costs, electricity tariffs, capacity factors, and baseline conditions, which may give different results.

1.3.1 Implications of Different CO₂-Prices

Depending on the CO₂-price and the baseline scenario, the discounted net present value of the CERs represents a value of between 5-30% of the project’s capital cost. Even at the lower rate this is a significant amount and would influence the financial viability and architecture of the project.

A five-fold increase in the value of CERs—from US\$2 to US\$10—raises the project’s return on equity by about 8%. This indicates that the project’s financing is not overly sensitive to CO₂-price changes. It means, among other things, that once the financing is secured, then small changes in the actual value of the CERs would be unlikely to influence the project’s financial results significantly.

1.3.2 Implications of Different Baselines

The approximate 20% difference between the “best” (181,465 tCO₂/annum) and the “worst” (147,513 tCO₂/annum) baseline examined means an increase of the project’s return on equity by between 0.4% (US\$2) and 1.66% (US\$10), respectively. Thus the project’s finances are not very sensitive to changes in the baseline either. When evaluating different baseline scenarios the project developer should therefore not simply try to pick the scenario which maximizes emission reductions. The developer should also take into account other aspects, such as ease of establishing and verifying the baseline and the certification costs, which will vary depending on choice of baseline.

The income earned by a wind project could be increased either by reducing the wind energy costs or by achieving a higher electricity price (tariff). These two approaches are independent of each other, but they are not equally beneficial: Higher electricity tariffs would have major implications for the project economy, but production cost reductions, unless they are significant, would not. In 1986-87, Egypt embarked on an economic adjustment program to address its low energy prices by correcting a costly subsidization policy that kept prices from rising and which encouraged increasing energy consumption.⁵ More recently this policy was abandoned due to political and social reasons, and it is unlikely that this decision will be reversed any time soon.

⁵ For instance, petroleum products subsidies reached US\$ 3.5 billion in 1985. *The Arab Republic of Egypt: Initial National Communication on Climate Change—Prepared for the United Nations Framework Convention on Climate Change* (Egyptian Environmental Affairs Agency, June 1999), p. 31. More

Beginning in the early 1970s, the wind industry in Europe and North America has benefited greatly from various green-electricity schemes that have made it possible to sell wind electricity at a price above the market price of power. These schemes have been intended to stimulate the development of wind power as a source of renewable energy. Concerns about environmental protection (e.g., acid rain and global warming) and energy security (e.g., the energy crisis in the early 1970s) have been the key drivers behind these schemes. In a EU-Mediterranean trade area that included renewable values, Egypt would have access to such a market, but such a market will not materialize within the foreseeable future. Nor is Egypt planning to introduce a domestic market for green electricity any time soon.⁶

It currently is cheaper to produce electricity from natural gas than from wind energy in Egypt. Gas-fired power plants will remain the preferred option as long as this situation continues. But an increase in the domestic gas price, which seems likely if Egypt begin to sell to the European gas market, would increase the cost of electricity from gas-fired power plants and would make wind power more competitive.

1.3.3 Risk Mitigation through CO₂ Revenues

Securing the income stream from selling the creditable emission reductions from the Zafarana project would have a beneficial effect on the project's financial structure. Not only would the CERs mean increased income to the project, but they would also constitute an income stream that is separate from the sales of electricity. This diversification in income would reduce the project's overall financial risk and therefore the project's cost of capital. Since the CERs would be valued and sold in an OECD currency (such as US dollars or Euros), this income stream would not be subject to normal developing country currency risk. In comparison, the power generated from a CDM wind park would as a rule be sold in the local currency, which would be subject to country and currency risk.

1.4 Sustainability and Socio-Economic Benefits

The report shows that the prospects for the sustainability of the Zafarana project are positive. From the standpoint of project viability, all sustainability indicators except cost-effectiveness show very favorable conditions for their achievement by the project. Indeed, the project conforms to the national development priorities; the risks of economic and technical obsolescence are low; the integration into the grid poses no significant problems; and human and institutional resources as well as local expertise to manage and operate the project at standard levels of efficiency are available.

From an energy sector perspective, Egyptian government authorities expect that wind technology will further the achievement of development objectives that are broader than those confined to techno-economic considerations. Due to its relative size, the Zafarana project's contribution to the sustainability of the energy system and, more generally, to the health of the economy is marginal. However, the issue of the project's impact on national development goals goes beyond its technical boundaries, and the Zafarana project must be seen as part of a process towards more environmentally sound and diversified energy systems where wind power is called to play a

generally, see ESMAP, *Arab Republic of Egypt: Energy Sector Assessment* (World Bank, Washington DC: ESMAP Report no. 189/1996).

⁶ It is not envisaged that countries in the developing world soon will introduce green energy markets. Some transitional economies, such as Poland, have recently taken some steps to introduce markets for green electricity, but such initiatives are few and far between.

relevant role. In this regard the project effectively satisfied the requirements with respect to resilience, technological diversification, and environmental protection. A significant wind power capacity in the total power supply would decrease the power system's vulnerability to unexpected contingences and possible fluctuations due to hydrology conditions and oil prices. Moreover, the wind technology could trigger the development of industrial activities with considerable implications for the diversification of the national technological fabric. Finally, due to its location characteristics, potential negative impacts on the environment, such as land use requirements, noise and visual impacts, would be irrelevant.

1. INTRODUCTION

Beginning in the late 1980s, a series of international negotiations has been conducted with the explicit aim of protecting the global climate system against expected negative disturbances caused by rising concentrations of human-induced greenhouse gas (GHGs) emissions in Earth's atmosphere. The United Nations Framework Convention on Climate Change (UNFCCC) was signed at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, and a protocol to be added to the UNFCCC was negotiated in Kyoto in 1997. The Kyoto Protocol, which presumably will enter into force in 2003, will establish the Clean Development Mechanism (CDM) as an important and innovative global instrument for climate cooperation between industrialized countries and developing countries.

This document is intended to raise awareness about the opportunities created by the CDM and to begin explore its implications for investments in wind power in developing countries. It seems likely that the Kyoto Protocol and the CDM will soon enter into force. Yet, the wind power industry, potential investors in industrialized countries, lenders, potential developing country hosts, and the international community at large are mostly unaware of the CDM and its potential financial implications for investments in renewables in developing countries.

The document is intended to be a guidance document for project developers, investors, lenders, and CDM host countries involved in wind power projects in the CDM with at least 15 MW installed capacity. It focuses on those issues that arise especially in the context of the Kyoto Protocol and the CDM. These issues are not addressed in a conventional feasibility study of a wind power project. The document tests and compares internationally agreed methodologies, or approaches at least, to baseline development. This is done in the context of an actual wind park, namely a DANIDA-sponsored wind park located in Zafarana, Egypt, on the west coast of the Gulf of Suez about 110 kilometers south of Suez.⁷ Thus, the 60 MW wind farm in Zafarana—the largest wind farm in Africa—serves as a hypothetical wind power project in the CDM. It must be stressed that the Zafarana wind park is selected for illustrative and pragmatic purposes only. The results presented in this report therefore do not reflect the actual conditions of this wind park.

There were several pragmatic reasons for selecting Zafarana as a case example of a CDM wind project. First, this choice makes it possible to utilize a simulation tool, the ES³-model, to explore the system implications of the wind park. The ES³-model, which has been developed at the Systems Analysis Department at Risø National Laboratory, uses quite disaggregated data on the Egyptian electricity system. Second, the Wind Energy Department at Risø National Laboratory conducted the wind measurements in the Zafarana project area. Third, the case example is able to build on a recent study that also examines the Zafarana wind park from the perspective of the CDM.⁸

Once they enter into force, the Kyoto Protocol and the CDM will create an international legal and regulatory framework for foreign direct investments in GHG offsets in developing countries. Chapter 2 will describe the emerging regulations and rules under the Kyoto Protocol and the CDM. The chapter will also introduce and explain key issues, such as baselines and additionality, and will present the CDM project cycle.

⁷ The Danish Agency for Development Assistance is abbreviated as DANIDA.

⁸ NREA/Risø National Laboratory, "Pre-Feasibility Study for a Pilot CDM Project for a Wind Farm in Egypt" (October 2001: ENG2-CT1999-0001).

Chapter 3 will present an overview of the baseline concepts and approaches that are relevant for regular-size (i.e., non small-scale CDM projects) wind power projects in the CDM. Chapter 4 will test and compare internationally agreed and accepted approaches to the development of so-called standardized baselines. Chapter 5 will focus on the development of so-called project-specific baselines through the application of model-based simulation tools.

In chapter 6, the main methodologies for and approaches to financial assessment of wind projects under the CDM will be presented. A model tool to study the impact of the choice of the baseline and the electricity price profile on the financial viability of a wind park will be presented in an appendix to chapter 6. Chapter 7 will address the important issue of environmental sustainability and the socio-economic benefits created locally by a CDM project in the host country. Using a generic set of sustainability indicators, this chapter will make a qualitative assessment of the Zafarana wind park. And in an appendix to chapter 7, a framework for quantifying the socio-economic benefits and costs of CDM projects is illustrated in the context of the Zafarana case example.

The various baselines presented and explored in this guidance document estimate the amounts of CO₂ that supposedly would be emitted in the absence of the Zafarana wind farm. Because wind power is displacing insignificant amounts of non-CO₂ Kyoto gases,⁹ and only gives rise to exceedingly modest amounts of GHGs,¹⁰ this document is only concerned with reductions in CO₂ emissions as a result of the Zafarana wind project.¹¹

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⁹ The six gases regulated under the Kyoto Protocol are carbon dioxide (CO₂), methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride.

¹⁰ For a discussion, see chapter 7.

¹¹ The production of the blades, the nacelle, the tower, etc, the exploration of the material and the transport of equipment result in energy consumption and, as long as the energy sources are based on fossil fuels, lead to (indirect, off-site) emissions. For emissions of SO₂, NO_x, and CO₂ from wind technology, see, Thomas Ackermann and Lennart Söder, "Wind Energy Technology and Current Status: A Review", *Renewable and Sustainable Energy Reviews* 4 (2000), 351-352. See also Robert Y. Redlinger, Per Dannemand Andersen, and Poul Erik Morthorst, *Wind Energy in the 21st Century* (Palgrave, Hampshire: 2002), pp. 158-163.

2. THE UNFCCC AND THE CDM

Article 12 of the 1997 Kyoto Protocol establishes the Clean Development Mechanism (CDM) as the international regulatory framework for foreign direct investments in additional GHG mitigation projects in developing countries. With the CDM, investors from industrialized countries and countries with economies in transition—the so-called Annex-I countries (see Box 1)—will be able count real, measurable, and long-term emission reductions achieved in developing countries against their commitments to reduce GHG emissions.

Box 1: Annex-I Countries

In the UNFCCC the industrialized countries and the countries with economies in transition are referred to, collectively, as the Annex-I countries: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Czech Republic, Denmark, the European Union, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, and the United States. The developing countries are referred to as the non-

The objectives of the CDM are to give industrialized countries with high GHG mitigation costs access to low or lower-cost GHG mitigation projects in developing countries and to benefit developing countries by supplying GHG offsets—formally certified emission reductions, or CERs, in the Kyoto Protocol—to industrialized countries. Equally important, the CDM is also meant to stimulate sustainable development in the developing countries where the CDM projects will be implemented, the so-called host countries.¹² Note that it is entirely up to the host country to decide whether a CDM project would contribute to its national sustainable development. No international institution or organization is formally assessing whether CDM projects would satisfy this criterion.

2.1 Additionality

According to the Kyoto Protocol, it is possible to generate GHG emission reductions by investing in CDM projects that emit less GHGs than would have otherwise been emitted by a project or an investment. The former project is referred to as the alternative, while the latter project is referred to as the base case, or the reference case. The reference case is a counterfactual based on an estimate or a prediction; it cannot be measured empirically beforehand or *ex ante*. The GHG emission reductions are the difference between the emissions in the base case and in the CDM project, respectively.

The Kyoto Protocol stresses that the GHG emission reductions must be real, measurable, and long-term in order to be credible.¹³ The Protocol specifies that only those “reductions in emissions that are additional to any that would occur in the absence of the certified project activity” would generate CERs.^{14,15} In this context, “additional” is an alternative term for “real”.

¹² For instance, as viewed from a Southern African perspective: “A CDM project is a development project, driven by market forces, that reduces GHGs”. Randall Spalding-Fecher, ed., “The CDM Guidebook: The Clean Development Mechanism of the Kyoto Protocol – A Guidebook for Project Developers in Southern Africa (Elan Press, 2002), p. 2.

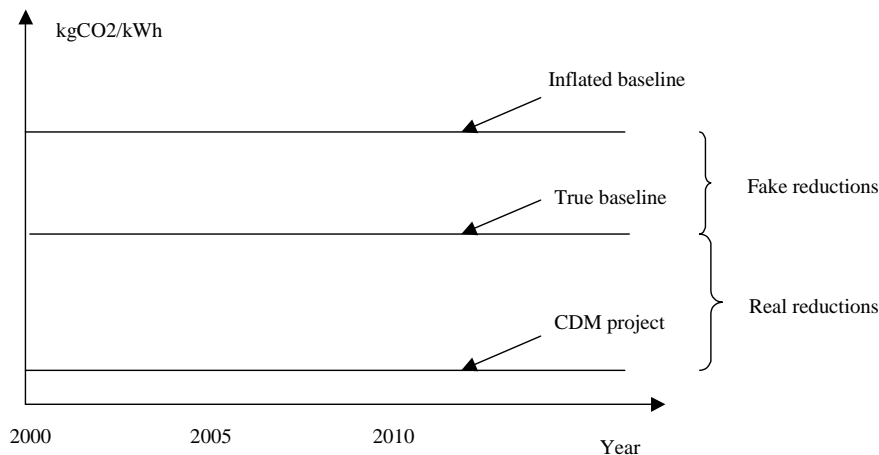
¹³ Article 12.5 (b).

¹⁴ Article 12.5 (c).

Both refer to emission reductions that would not have occurred in the absence of a CDM project. Only those reductions that are achieved over and above the base case emissions would be considered real or additional. This should prevent that credits would be earned by projects that would happen anyway (so-called “free-rider” projects). Bogus or false emission reductions, or emission reductions that cannot be measured or are short-term, would not be credible under the CDM.¹⁶

It is important that project developers address the additionality issue in a transparent and systematic fashion. It has often been observed that, unless preventive steps are taken, investors and host countries could intentionally overestimate CDM baselines in order to enhance revenues. Because a larger amount of GHG emission reductions would be attributed to a project than it would in fact generate, both the investor and the host developing country would have an incentive to exaggerate the amount of GHGs emitted in the base case (see Figure 1). But consistent, conservative, and verifiable methodologies would reduce and perhaps even prevent such baseline “inflation”.

Figure 1: Baseline inflation and implications on amount of CO₂ reductions generated.



Environmental additionality is the only additionality concept that is explicitly identified in the Kyoto Protocol and the Marrakesh Agreements.¹⁷ Nevertheless, other concepts or notions of additionality exist and may be important as well. The four main concepts are as follows¹⁸:

¹⁵ A “CER” is defined as a unit issued pursuant to Article 12 of the Kyoto Protocol and requirements thereunder, and is equal to one metric tonne of carbon dioxide equivalent calculated using the global warming potentials (GWPs) recommended by the Inter-Governmental Panel on Climate Change (IPCC).

¹⁶ For instance, if a forest fire re-releases the carbon sequestered in forest biomass by a CDM project, the project would generate only short-term, not long-term, reductions.

¹⁷ The government that are parties to the UNFCCC met in November 2001 in Marrakesh, Morocco. This conference, which was the seventh conference of the parties (abbreviated as COP-7), succeeded to reach agreement on a number of more detailed issues related to the CDM. See “*Report of the Conference of the Parties on Its Seventh Session, Held at Marrakesh from 29 October to 10 November 2001*,” (21 January 2002), FCCC/CP/2001/13/Add.2.

¹⁸ For definitional discussions and proposals for procedures for assessing additionality, see Stephen Meyers, “Additionality of Emissions Reductions from Clean Development Mechanism Projects: Issues and Options for Project-Level Assessment” (Berkeley: LBNL, 1999); Ram M. Shrestha and Govinda R.

1. environmental additionality (i.e. only those GHG emission reductions that are over and above the baseline are additional);
2. financial additionality (i.e. only those projects that would not have been invested in anyway are additional);
3. program additionality (i.e. only those project that are financed by new, additional government programs are additional); and
4. technology additionality (i.e. only those CDM projects that employ technologies that emit less GHGs than the base-case technology are additional).

It is, for obvious reasons, necessary that project developers are paying close attention to environmental additionality when checking whether a wind farm is additional or not. Chapter 3 presents a number of baseline concepts and approaches that are being used to test for environmental additionality. The Kyoto Protocol determines that projects that are not environmentally additional are ineligible under the CDM. Such projects would not be credible; in other words, they cannot generate CERs.

Although applying the concept of financial additionality can be complex and ambiguous in the context of concrete projects, the underlying concern is clear: CERs should only be earned by those projects that would not be sufficiently profitable or commercially viable without the revenues earned by selling the CERs.¹⁹ If not, it is argued, then the CDM's environmental integrity would be compromised since projects that would have happened anyway would earn both profit and CERs revenues. Even though the concept of financial additionality is not mentioned explicitly in the Kyoto Protocol, project developers are advised to pay close attention to it.²⁰ Chapter 6 discusses the concept further.

Program additionality, which although it is concerned with the *source* of funding may be seen as a variant of financial additionality, is identified explicitly in the Marrakech Accords.²¹ It is concerned with those situations where a government would use existing funds, not new or additional funds, to finance CDM projects. One example would be a government that finances CDM projects out of existing Official Development Aid (ODA) funds rather than new or additional government resources. Another example would be to invest the financial resources that the industrialized countries are committed to contribute within the framework of the UNFCCC—for instance, contributions to the Global Environment Facility (GEF)—in CDM projects.

Timilsina, "The Additionality Criterion for Identifying Clean Development Mechanism Projects under the Kyoto Protocol", *Energy Policy* 2002 30: 73-79.

¹⁹ There are several reasons why the financial additionality criterion often may be difficult to apply. First, as it is relatively easy to manipulate financial project parameters, this criterion may be met through "creative bookkeeping". Second, financial information about private company operations is usually proprietary information. Third, financial issues may not be significant for a company deciding whether to go forward with a particular business venture. See, e.g., "Criteria and Guidelines for Baselines: Outcomes of an Expert Workshop". Amsterdam, January 17-19, 2000.

²⁰ But note that e.g. PCF projects are subject to systematic financial additionality testing.

²¹ According to the Marrakesh Accords: "...public funding for clean development mechanism projects from Parties in Annex I is not to result in the diversion of official development assistance and is to be separate from and not counted towards the financial obligations of Parties included in Annex I". "Report of the Conference of the Parties on Its Seventh Session, Held at Marrakesh from 29 October to 10 November 2001," (21 January 2002), FCCC/CP/2001/13/Add.2, p. 20.

The concept of technology additionality is important, even though it is not identified explicitly in the Kyoto Protocol. It is appealing to project developers in those situations where determining the base case technology is unproblematic. One interpretation, or operationalization, of this concept is choosing the technology “on the margin”—that is, the technology or project selected by the most recent comparable investment—as the base case. This concept, and the related concept of “recent additions”, is examined in chapter 4.

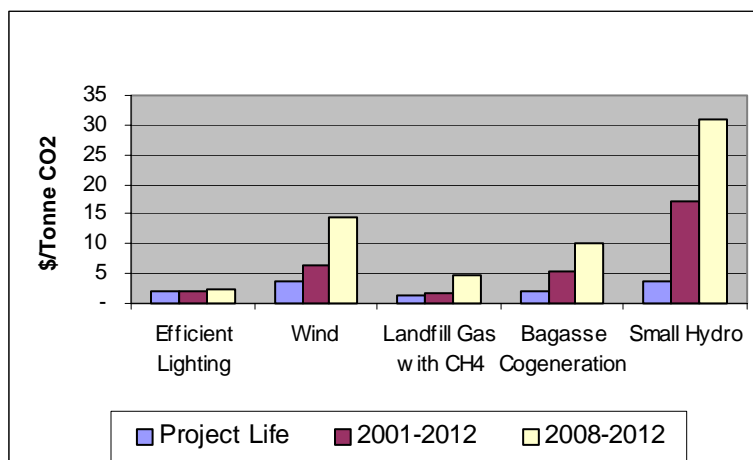
2.2 Crediting Periods

Under the CDM emission reductions achieved in the 2000-2008 period can be used to meet the commitments in the first five-year commitment or budget period, i.e., 2008-2012. Note that the eligibility conditions for projects that would generate emission reductions beyond 2012 have not yet been clarified in international regulation. This is obviously an important issue. To illustrate, think of a CDM wind park with a 20-year lifetime that would begin generating emission reductions in 2003. Under the current regulations the emission reductions achieved until 2012 would clearly be eligible. However, the emission reductions achieved from 2013 to 2023, a full ten-year period, would not be eligible.

That said, it is widely expected that the emission reductions that are generated over the entire lifetime of a project will be credible, eventually, under the Kyoto Protocol. If not, a significant portion of the reductions generated by wind projects, and by other technologies with long lifetimes, would have no value, a situation that would result in a significant disincentive to investing in those technologies.

To illustrate, Figure 2 indicates the sensitivity of the costs of CERs generated by projects with short lifetimes (efficient lighting; land-fill gas; bagasse co-generation) and projects with long lifetimes (hydro; wind) to the length of the crediting period. It illustrates that the costs of one tonne of CO₂ emission reductions generated by wind power could increase from US \$3.6 to \$14.4 if the crediting period was reduced from the entire project life of 20 years to instead the first commitment period.

Figure 2: Indicative costs of carbon credits under different crediting period validity conditions.



Source: Alternative Energy Development, “The Sensitivity of the Cost of GHG Credits to Credit Eligibility Period.” (A Study Prepared for the World Bank Prototyp Carbon Fund, September 2000).

Two alternative approaches to eligible crediting periods are identified in the Marrakesh Accords from November 2001:

1. A crediting period of maximum seven years which may be renewed no more than two times. It is necessary that, for each renewal, the CDM's executive board (see Box 3) is informed that the original baselines is still valid or has been updated; or
2. A maximum of ten years with no option of renewal.

Self-evidently, the first alternative would be preferable for wind power projects because their project lifetimes often exceed ten years. Importantly, this alternative allows for updating of the data used in setting the baseline, but it apparently does not to allow for a change of the baseline approach itself. The need for updating the baseline and perhaps revising the baseline method is most pertinent for CDM projects with long lifetimes.

2.3 Adaptation Surcharge and Administrative Expenses of the CDM

According to current international regulations two per cent of the CERs generated by the CDM are earmarked for the so-called Kyoto Protocol Adaptation Fund for developing countries that are particularly vulnerable to the negative effects of climate change.²² In practice, this means that two percent of the CERs generated by a CDM project would be deducted from the project. Note that projects that are implemented in least developed countries (see Box 2) are exempted from this rule.

Moreover, a share of the proceeds from CDM projects shall be used to cover the administrative expenses of the CDM. The Conference of the Parties to the UNFCCC will decide the level of the share of proceeds for the administrative expenses of the CDM. The share will most likely constitute a certain portion or percentage of the CERs generated by individual projects.

Box 2: The LDCs

In 2002, there were officially forty-nine LDCs: Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Cape Verde, Central African Republic, Chad, Comoros, Democratic Republic of Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, The Gambia, Guinea, Guinea Bissau, Haiti, Kiribati, Lao People's Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Rwanda, Samoa, Sao Tome and Principe, Senegal, Sierra Leone, Solomon Islands, Somalia, Sudan, Togo, Tuvalu, Uganda, United Republic of Tanzania, Vanuatu , Yemen, and Zambia.

2.4 Supplementarity

The issue of supplementarity—i.e., to what extent should the Kyoto targets be achieved through domestic measures?—is addressed in the Kyoto Protocol and in other international regulatory

²² “*Report of the Conference of the Parties on Its Seventh Session, Held at Marrakesh from 29 October to 10 November 2001*,” (21 January 2002), FCCC/CP/2001/13/Add.2, p. 23.

instruments in the climate area.²³ Precise regulations have so far not been established in this area. Nonetheless, project developers are advised at an early stage to contact the relevant national authorities about this issue in order to check whether it could have any implications for the CDM project that they intend to develop.

2.5 Exemptions for Small-Scale CDM Projects

It is widely recognized internationally that small energy efficiency and renewable energy projects would incur proportionally higher transaction costs than regular CDM projects if all projects would be subjected to the same stringent rules and regulations in regard to the baseline and additionality testing. This would be undesirable because it would make small energy efficiency and renewable energy projects relatively more costly and less attractive and competitive against regular-size projects. Instead, it is seen as important that small-scale projects will be “fast-tracked” through the CDM approval process.

The preliminary rules in this area were first formulated in 2001. They define three categories of small-scale CDM projects as follows:

1. Renewable energy project activities with a maximum output capacity equivalent of up to 15 MW (or an appropriate equivalent);
2. Energy efficient improvement project activities which reduce energy consumption, on the supply and/or demand side, by up to the equivalent of 15 GWh/year; and
3. Other project activities that both reduce anthropogenic emissions by sources and that directly emit less than 15 kilotonnes of CO₂ equivalent annually.

The CDM executive board is currently examining technical issues in regard to project types, baseline methodologies, leakage, monitoring etc for each of these three project categories. It is foreseen that rules for small-scale CDM projects will be decided in 2002/2003.

Wind parks with more than 15 MW of installed capacity will likely be subject to the same set of rules as regular CDM projects. Project developers should thus assume that the rules and regulations pertaining to regular CDM projects apply to all wind projects except those that are eligible as small-scale projects.

Box 3: The Executive Board of the CDM

The executive board of the CDM is responsible for the supervision of the CDM, including registration of CDM projects, maintaining a publicly available database of CDM project activities, accreditation of independent verifiers and certifiers, approval of baseline and monitoring approaches, and issuance of CERs. It is comprised of ten members from the Parties to the Kyoto Protocol. The first meeting of the executive board of the CDM took place in November 2001. For further information, see <http://unfccc.int/cdm/>

²³ According to the Marrakesh Accords, “the mechanisms shall be supplemental to domestic action and that domestic action shall thus constitute a significant element of the effort made by each Party included in Annex I to meet its” climate commitments to control or reduce GHG emissions. “*Report of the Conference of the Parties on Its Seventh Session, Held at Marrakesh from 29 October to 10 November 2001,*” (21 January 2002), FCCC/CP/2001/13/Add.2, p. 2.

2.6 Project Boundary and Emissions Leakage

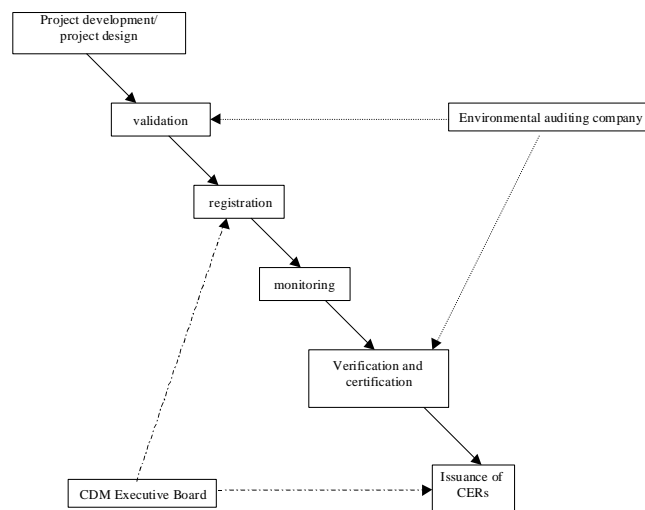
The project boundary or the monitoring domain should be defined in a way such that it covers all significant anthropogenic GHG emissions that are reasonably attributable to a CDM project. Emissions leakage is defined as the increase in emissions which occur outside the boundary of a project, and which is measurable and attributable to the CDM project. Leakage could reduce the amount of net emissions from CDM projects. Internationally, much attention is being paid to emissions leakage.

A distinction needs to be made between wind projects that are connected to the electric power grid and off-grid projects. Projects involving on-grid power generation must be viewed as part of a larger system—the proper project boundary is not defined by the physical site. Instead, in the case of big grid-connected wind parks, the electric power grid defines the project boundary. Possible leakage effects would occur at the regional/national level, as defined by the grid.²⁴ It seems useful to establish standardized default baseline values for small off-grid wind projects.²⁵ Such default baselines values would probably need the approval of the CDM executive board.

2.7 The CDM Project Cycle

There are four main phases or steps in the CDM project cycle (see Figure 3): (1) project development or project design; (2) validation and registration; (3) implementation and monitoring; and (4) verification and certification (i.e., issuance of CERs). These steps are common to all CDM projects, although they may be simplified and fast-tracked in the case of small-scale projects. Different actors are involved at the various steps in the project cycle.

Figure 3: Steps in the CDM project cycle and actors involved.



²⁴ This ignores possible international effects occurring where national grids are interconnected.

²⁵ See Table B-1 in “Annex B to Attachment 3: Indicative Simplified Baseline and Monitoring Methodologies for Selected Small-Scale CDM Project Activity Categories List”. <http://unfccc.int/cdm/Panels/ssc/annexb.pdf>. See also recommendations in UNEP/OECD/IEA, *UNEP/OECD/IEA Workshop on Baseline Approaches: Possibilities for Standardised Baselines for JI and the CDM: Chairman’s Recommendations and Workshop Report* (UNEP, OECD, IEA, 2001).

The main activities at the various steps in the CDM project cycle are summarized below.

2.7.1 Project Development/Project Design Phase

Recent experience shows that not all project ideas and concepts can be developed into implementable CDM projects that would reduce CO₂ (and/or other GHGs) and also would attract private or public financing. Project screening is a useful exercise that at an early stage can help project developers, investors, and host countries to identify unpromising project candidates. It is useful early on to check whether a project would:

- reduce GHG emissions;
- generate profits, i.e. returns are acceptable to investor and/or the cost of the generated GHG emission reductions are low;
- has clear boundaries, i.e. the parties and sites involved are well-defined;
- the GHGs in the base case and in the CDM project can be determined fairly easily;
- deliver tangible benefits in the host country that increase the probability of effective project implementation;
- the technology should be feasible and established;
- participants are able to undertake the project; and
- implementation would not be risky due to the political, economic, financial, or regulatory environment in the host country.

Project participants shall include, as part of the project design documents, a monitoring and verification protocol (MVP).²⁶ This would require identifying:

- what is to be monitored, especially GHGs but perhaps also sustainable development indicators;
- methods used;
- data needs;
- data gathering methods; and
- formulas for calculating emission reductions.

To achieve impartiality and reliability, the MVP could be prepared by a different environmental auditing company than that which would be responsible for the verification of the project.

2.7.2 Validation and Registration

Validation refers to an independent evaluation and approval of the design of a CDM project, including the project baseline and the MVP, by a so-called designated operational entity before a project can be implemented. The CDM executive board will accredit a number of independent environmental auditing companies, and perhaps additional organizations, to perform the validation, verification, and certification of CDM projects.

To be validated successfully, a project must:

²⁶ See the Project Design Document (PDD). <http://unfccc.int/cdm/cdmpdd.htm>. The contents of the project design document (PDD) are formally defined in Appendix B of the report of the seventh meeting of the parties to the UNFCCC. “*Report of the Conference of the Parties on Its Seventh Session, Held at Marrakesh from 29 October to 10 November 2001*,” (21 January 2002), FCCC/CP/2001/13/Add.2, pp. 43-45.

- meet essential criteria for CDM projects set out in the international regulation—e.g., the participating countries are parties to the UNFCCC and the Kyoto Protocol (i.e., eligibility of the partners);
- reduce GHG emissions—i.e., the soundness of the baseline should be established (i.e. eligibility of the project);
- identify the quantity of emission reductions that are expected to be earned by the project;
- meet sustainability goals of host country; eventual indicator test (i.e. eligibility of the project);
- be compatible with national development plans;
- be implementable;
- propose sound monitoring and reporting methods and a MVP; and
- include an agreement on the sharing arrangement for GHG benefits.

The validator, which will often be an internationally experienced and respected environmental auditing company, will prepare a validation report which likely will cover the above-mentioned issues. The validation report will then be submitted, together with the project documents, to the relevant national authorities in the investor and host countries for registration. Subsequently, the validation report and the project documents will be submitted to the CDM executive board for registration of the planned project. If a review of the proposed CDM project is not requested, the registration will be considered final eight weeks after the CDM executive board has received the request for registration.

Registration is the formal acceptance by the CDM executive board of a validated project as a CDM project. Registration is a prerequisite for the verification, certification, and issuance of CERs related to a project. In reviewing the CDM project design documents the designated companies and organizations appointed to perform the validation shall follow a procedure defined under the Kyoto Protocol. The baseline and monitoring approaches will be compared with the approaches approved by the CDM executive board.

2.7.3 Monitoring

Monitoring is the systematic surveillance of the performance of the project by the implementer(s) by measuring, evaluating, and archiving of performance-related indicators. Monitoring will need to follow agreed and established rules and standards when they become available in the context of the Kyoto Protocol and the CDM. Specifically, monitoring will need to follow the steps, procedures, and methods defined in the MVP developed for the project. The MVP will have to be accepted by the project participants and will be part of the project agreement.

2.7.4 Verification and Certification

Verification is the periodic independent review and *ex post* determination by an independent verifier of the monitored GHG reductions that have occurred as a result of the CDM project. Verification will be governed by the MVP or by a similar set of guidelines in accordance with national and international requirements. On the basis of a satisfactory review of the project's baseline, information and data collected on performance-related indicators, and project site visits, the verifier will issue a positive valuation report. Thereafter, after the project begins operating, the verifier will verify the emission reductions generated by the project—the activities of the verifier are quite similar to those found in established environmental auditing schemes. The verifier then issues a report for each verification period which covers all relevant items in a transparent manner and quantifies the emission reductions achieved during the validation period.

It should be possible for an independent third part to reproduce the findings and reach the conclusions contained in the report.

Certification is the written assurance by the accredited verifier that a CDM project achieved the GHG reductions as verified. It is a legal act that will need to be in accordance with national and international laws and regulations that are still to be agreed. It will usually be based on the verification report prepared by the verifier and submitted to the CDM executive board. The certificate will likely state that the emission reductions achieved can be used to meet commitments under the Kyoto Protocol; thus, the certificate will create “certified emission reductions” under Article 12 (i.e. the CDM) of the Kyoto Protocol. The verifier and certifier is accredited by the CDM executive board and acts on behalf of, and it accountable to, the parties to the UNFCCC. The details of verification and certification within the Kyoto Protocol still need to be worked out by the member governments to the UNFCCC.

3. BASELINES FOR WIND POWER PROJECTS

3.1 Introduction

Baseline development is arguably the most conceptually and technically difficult step in developing a CDM project. This chapter discusses various methodologies for baseline development, the base case and the CDM alternative, and the comparison of the base case and the alternative. It discusses a number of baseline concepts and methodologies, ranging from project-specific baselines to standardized, or multi-project, baselines. In chapters 4-5, these methodologies and concepts are explored in the context of the Zafarana wind park.

The various baseline methodologies and approaches that are emerging in the UNFCCC context are briefly outlined below. Note that well defined, internationally accepted and agreed CDM baseline methodologies and approaches do not exist at this point. Thus, at this stage, some flexibility exists with regard to which approaches to follow when developing the baseline for a wind project. Although this situation unavoidably creates some uncertainty, it could be quite useful in the early stages of the CDM market, since it allows for learning-by-doing and experimentation with different methodologies. It is expected, however, that the CDM executive board will soon identify those methodologies and approaches that should be followed when developing the baseline. It will otherwise not be possible to estimate, validate, monitor, verify, and certify CDM projects in a consistent and cost-effective manner. Note, in addition, that project developers may propose new methodologies for baseline development to the CDM executive board.²⁷

3.2 Baselines

The baseline for a CDM project is the scenario that reasonably represents the anthropogenic or human-induced GHG emissions that would occur in the absence of the CDM project. A baseline shall cover emissions from all gases, sectors, and sources that exist within the project boundary.²⁸

Emissions from the base case and from a CDM project in the energy supply area may generally be conceived of as follows:

$$GHG\ emissions = Project\ output * energy\ use/output * GHG\ emissions/energy\ use$$

GHG emissions are a function of output/activity level; energy intensity or energy efficiency; and carbon intensity. A change in one or more of these components—e.g., reducing the activity level; enhancing energy efficiency; or switching to cleaner fuels—would affect the overall amount of GHG emissions from a project. Wind power projects in general address the third component of this formula.

The first step in the GHG assessment of an energy supply project is to forecast or project the future supply, the mix of generation resources or types, and the energy demand for the entire lifetime of the CDM project. For instance, a baseline for the Zafarana wind farm would be a prediction or projection of energy use and associated GHG emissions into the future that takes

²⁷ See the Project Design Document, Annex 3. <http://unfccc.int/cdm/cdmpdd.htm>.

²⁸ “*Report of the Conference of the Parties on Its Seventh Session, Held at Marrakesh from 29 October to 10 November 2001*,” (21 January 2002), FCCC/CP/2001/13/Add.2, p. 36.

into account the historical conventional practices and the current socio-economic situation in the affected area. Wider national, regional or even global economic trends that may affect a project could also be reflected in the baseline scenario.

The implications of various policies and measures, national as well as international, are often reflected in baselines. It is often appropriate to attempt to include the likely future consequences of significant policies and measures, action plans, restructuring plans, etc., for a sector in the baseline. It is recommended to follow a conservative approach to future government policies. It seems that the best one can do is to reflect the likely effects of government policies that are already being implemented or have a high likelihood of implementation. It is therefore wise to take into account a country's track record in the area of policy implementation when forecasting the expectable effects of government policies. Assuming that government policies would be completely implemented and would fully achieve their stated goals will seldom be a credible assumption.

It is important to apply a well-defined and consistent approach or methodology when developing a baseline for a CDM project. The method should be rigorously and consistently applied, the necessary data and information should be collected and employed, and the assumptions used in calculating the baseline should be stated explicitly. Importantly, this makes it possible for other parties, such as independent verifiers of projects and other interested parties, to re-calculate and check the soundness of the baseline.

In some situations it could be necessary to estimate more than one baseline. Several approaches and concepts are identified in the international rules and regulations (see section 3.4) and it is useful to compare different baseline concepts and methodologies, especially the sensitivity and robustness of the different baseline approaches. Multiple baselines also seem preferable for other reasons. In particular, creating several baselines would be useful and perhaps even necessary in cases where there is considerable uncertainty about future developments with significant impact on the project. But too many or unrealistic baselines should not be developed since this would increase the project development costs unnecessarily.

Generally, the project developer should select the most plausible or realistic baseline. If several, equally plausible baselines exist, the baseline generating the largest amount of emission reductions should be selected. On the other hand, to avoid overestimating the amount of emission reductions generated, one could select the most conservative baseline. Another approach is to calculate a simple average value of different baselines developed for a project. For instance, a recent baseline study suggested an average of four plausible multi-project baseline scenarios as the baseline for a wind power project in Jamaica.²⁹ In this case, the baseline was a conservative guess, which was lower than some of the baselines and represented a reasonable middle ground estimate. In case of project-specific baselines, it might be better to use a weighted average of a number of separate baselines, reflecting their relative probability.

²⁹ EcoSecurities, *Wigton Wind Power Project, Jamaica: Evaluation of Potential Greenhouse Gas Emission Reduction Value* (EcoSecurities, June 2000). But note that a revised version instead adopts a "combined margin" approach. See EcoSecurities, *Baseline Study Document for the Wigton Wind Farm Project* (EcoSecurities, August 2002). The combined margin approach takes into account a project's effects on GHG emissions of (i) the operation of current and future power plants (referred to as the operating margin) and (2) on what and when new power plants will be built (referred to as the built margin). See Kartha, Lazarus, and Bosi (2002).

Project developers are strongly advised to follow internationally agreed technical procedures and to utilize internationally approved energy and emission data whenever available. In particular, it is recommended to utilize the methods, factors, and values that are suggested in the Intergovernmental Panel on Climate Change (IPCC) *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*.³⁰ Alternative values and data—e.g., carbon emission factors (tC/TJ) and calorific values (TJ/10³ tonnes)—may be used if the IPCC does not provide relevant values. The International Energy Agency (IEA) provides emission factors for the life-cycle of energy projects (rather than isolated project emissions), and the UNFCCC secretariat has published an overview of emissions factors and activity data used in energy and non-energy sectors in some developing countries.³¹ It is necessary, however, that the executive board of the CDM accepts such alternative factors and values.

3.3 Project-Specific and Standardized Baselines

Two conceptually different notions or approaches are available for project developers—standardized, multi-project baselines or project-specific baselines.³² The first type of baseline makes it possible for multiple projects of *the same type* (e.g. renewables projects) implemented under similar conditions to use the same baseline. Standardized approaches may not be as accurate as project-specific baselines in calculating GHG reductions, at least at the level of individual CDM projects, and might for this reason be seen as less environmentally credible. On the other hand, standardized approaches lower the transaction costs and are therefore more likely to facilitate investments in CDM projects.³³ The challenge is to strike the right balance between accuracy (environmental integrity) and the costs of developing (and monitoring) a baseline (transaction costs).

3.3.1 Project-Specific Baselines

Although a precise, internationally agreed and operationalizable definition for regulatory purposes does not yet exist, project-specific baseline methodologies and concepts are well-known and have often been used in project development. This type of baseline reflects the specifics of individual projects as well as the socio-economic and policy settings in which they are placed. Project-specific baselines are sensitive to the assumptions made about economic development, technological change, and population growth. This type of baseline may also reflect other factors with a significant impact on future energy supply and energy demand. Examples are national and regional development plans, energy sector reforms, and development plans for the national electricity grid. It is important that the baseline methodology is transparent and consistent and takes into account all relevant factors.

It may often be necessary to use energy, economic, or financial models to develop project-specific baselines. To explore this approach, a simulation model is used in this report to estimate

³⁰ On IPCC emission factors, see IPCC, 1997. <http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm>.

³¹ See, e.g., FCCC/TP/1999/3, 24 October 1999, *Comparative Analysis of Emission Factors and Activity Data Used for the Estimation of Greenhouse Gas Emissions in the Energy and Land-Use Change and Forestry Sectors for Some Developing Countries*. <http://www.unfccc.de/resource/docs/tp/tp0399.pdf>.

³² See, for instance, S. Meyers, C. Marnay, K. Schumacher, and J. Sathaye, *Estimating Carbon Emissions Avoided by Electricity Generation and Efficiency Projects: A Standardized Method (MAGPWR)* (Berkeley, CA: Lawrence Berkeley National Laboratory, 2000).

³³ See, e.g. OECD and IEA, *Emission Baselines: Estimating the Unknown* (Paris: OECD/IEA, 2000); Tellus Institute, Stockholm Environment Institute and Stratus Consulting, *Evaluation of Benchmarking as an Approach for Establishing Clean Development Mechanism Baselines* (Boston, 1999).

and explore the impact of the Zafarana project on the Egyptian electric system and on CO₂ emissions. A dynamic baseline based on assumptions about future electricity demand growth will be developed in chapter 5. Electricity demand is driven by changes in, among other things, economic growth, population growth, prices, and technologies.

3.3.2 Standardized Baselines

In most cases standardized, multi-project baselines are not based on model outputs, are less complex, and depend less upon detailed data collected at the project level. An example of a highly aggregated multi-project baseline is the average, or perhaps above-average, emission rate, measured as tCO₂/MWh, for the entire electric power grid. This emission rate could serve as a benchmark, and GHG emission reductions would be calculated by comparing the CDM project's emission rate times project output measured in kWh to the benchmark value. This is one of the standardized approaches examined in chapter 4.

In order to better capture the generation technologies and fuel mix that is in place in a country, it might seem more useful to use a weighted average of all power plants as a benchmark. But this approach is not always straightforward or unproblematic either. One issue is the mix of non-fossil and fossil sources of electricity generation. For example, in 1996-1997, hydropower constituted around 21% of the total installed capacity in Egypt.³⁴ Inclusion of hydropower in the base case would lower the baseline—hydropower is emission free—thus reducing the amount of CO₂ displaced by a renewable energy project.³⁵ Chapter 4 explores this approach in the context of the Zafarana wind park.

Sometimes so-called static technology baselines are suggested in CDM project documents. For example, calculating the GHG emission reductions by a wind farm would be straightforward if it is assumed that a wind farm would displace a conventional gas-fired power plant: First, the GHG emissions from the gas-fired power plants should be estimated; Second, the emissions from the gas-fired power plants and the emissions from the wind farm should be compared. In the Egyptian context, one should compare the wind park to a natural gas boiler-turbine plant.

In all cases, the crucial question is the following: What is the most credible best guess for the base case technology? When taking into account the opportunities and constraints in the energy sector, is it really believable that a new wind park would displace conventional gas-fired power plants? And would conventional gas-fired power plants be the most likely base case technology for the entire lifetime of the CDM project? In other words, no need for updating the baseline at some point? This baseline approach is explored in chapter 4.

It is possible, finally, that government goals that are formulated at the level of a particular technology, a sector, or a region could be used to set the baseline for a CDM project. An example of this would be a power sector expansion plan. Two advantages of this approach are simplicity and low(er) development cost. But this approach could be problematic. For example, policy goals and action plans of governments might be unrealistic, might be defined imprecisely and/or inconsistently, might not exist for certain areas and sectors, might even conflict, etc. It therefore is important to consider alternative approaches. This approach is not explored in this manual.

³⁴ NREA/Risø National Laboratory, "Pre-feasibility Study for a Pilot CDM Project for a Wind Farm in Egypt" (Preliminary Draft, ENG2-CT1999-0001N, December 2000), p. 45.

³⁵ As an actual fact, hydropower can lead to methane emissions from rotting vegetation and carbon inflow from the catchment.

3.3.3 Fixed vs. Revised and Static vs. Dynamic Baselines

It is important to make a distinction between fixed and revised baselines. Once a fixed baseline has been established in the project development phase, it would remain valid for the entire project lifetime. Other baselines would be revised over the lifetime of a project. When and how they would be updated or revised would have to be defined at the outset of the project.

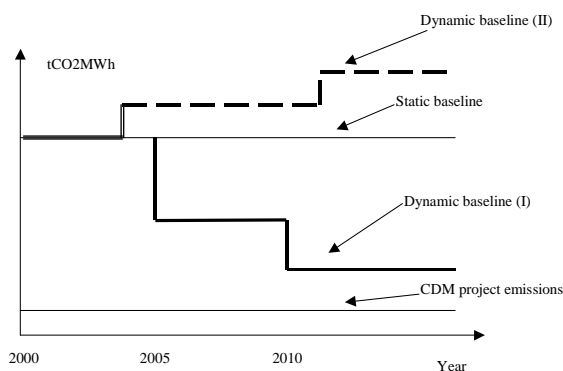
Note also another distinction, namely that between dynamic and static baselines. The former makes a projection *ex-ante* that assumes a change in important project parameters (e.g., energy efficiency changes at a certain per cent point per year), and thus a change in amounts of CO₂ emitted at various points over the life of a project. The latter type of baseline presents a simple static projection, for instance based on a historical level of CO₂ emissions.

Some of the key factors that could influence baseline changes over time are:

- Technological improvement;
- Energy conservation plans;
- Products structure change; and
- Fuel switching.

Figure 4 depicts two dynamic baselines. Dynamic Baseline I, marked with bold, could represent, for instance, the effect of phase-outs of obsolete technologies at fixed point in times. Dynamic baselines are relevant for projects that are carried out under conditions undergoing rapid technical improvement and innovation or environmental standards and regulations up-grade. But dynamic baselines are also relevant in the “opposite” situation, e.g., if a generation technology mix would become more based on fossil fuels in the future. For instance, a developing country that has largely exhausted its hydroelectric potential may plan to build coal-fired power plants in the future in order to meet an increasing demand for energy.³⁶ This case is illustrated by Dynamic Baseline II in Figure 4.

Figure 4: Static and dynamic baselines for CDM projects.



³⁶ See, for instance, “Electricity Generation Case Study” in OECD/IEA, *Emission Baselines: Estimating the Unknown* (Paris: OECD/IEA, 2000), pp. 99-163.

3.4 Internationally Approved Baseline Approaches and Concepts

International regulation recently established under the UNFCCC suggests implicitly that project developers can choose between project-specific and standardized concepts and approaches when developing actual projects. Thus, according to the text agreed to at COP-7 in Marrakesh, Morocco, in November 2001:

1. With respect to *project-specific baselines* it is pointed out that they should take “into account relevant national and/or sectoral policies and circumstances, such as sectoral reform initiatives, local fuel availability, power sector expansion plans, and the economic situation in the project sector”;³⁷ whereas
2. With respect to *standardized baselines*, project developers can select from among three different approaches:
 - (a) “Existing actual or historical emissions, as applicable”; or
 - (b) “Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment”; or
 - (c) “The average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 per cent of their category”.³⁸

Note that (a) and (c) are based on historic data. They are therefore measurable to the extent the necessary data exist and are available.

It should be underscored that international regulations in this area still are evolving. It is expected that the CDM executive board in the coming year or so will provide more precise definitions of the baseline methodologies and approaches to be used in project development. Project developers and other users and stakeholders should make sure that they are up-dated on international baseline approaches and methodologies.

³⁷ “Report of the Conference of the Parties on Its Seventh Session, Held at Marrakesh from 29 October to 10 November 2001,” (21 January 2002), FCCC/CP/2001/13/Add.2.FCCC/CP/2001/13/Add.2, p. 37.

³⁸ “Report of the Conference of the Parties on Its Seventh Session, Held at Marrakesh from 29 October to 10 November 2001,” (21 January 2002), FCCC/CP/2001/13/Add.2, p. 37.

4. STANDARDIZED BASELINES FOR ZAFARANA

Chapter 3 presented different types of baselines and baseline approaches, including those identified in the Marrakesh Accords and Declarations of November 2001. The Marrakesh Declarations identify three different categories of baselines—standardized baselines, project-specific baselines, and simplified baselines for small-scale CDM project activities. Although they do not define methodologies for setting standardized baselines, different approaches to standardized baselines are outlined, which can be translated into different standardized baselines for CDM projects. In the case of project-specific baselines, several options are available. In the case of an electricity supply project that would not replace an existing power plant, it is difficult to establish a unique project specific baseline. This is because grid-connected projects may replace a mix of (inefficient) plants, and it is seldom possible to identify a specific project or emission profile that a CDM project would replace. Thus, standardized baselines in the case of electricity supply project could be more relevant.

Before different plausible baselines for the Zafarana project are established, it is necessary to consider if the Zafarana wind farm project could qualify as a small-scale CDM project activity and, therefore, that project developers could follow a more simplified approach to the baseline. But, as already mentioned, renewable energy project activities with a maximum installed capacity of up to 15 megawatts fall into the first category of small-scale CDM project activities. Evidently, the 60 MW Zafarana project would fall outside this project category. Hence, it is necessary to develop either project-specific or standardize baselines for the Zafarana wind park.

Regarding project-specific baselines, the Marrakesh document specifies, as discussed in chapter 3, that they should take “into account relevant national and/or sectoral policies and circumstances, such as sectoral reform initiatives, local fuel availability, power sector expansion plans, and the economic situation in the project sector.” This clause may be interpreted to exclude renewable projects, such as the Zafarana wind farm, that are initiated by the government as part of its renewable energy policy. On the other hand, it leaves enough scope for a country to categorize any such initiative as a part of the CDM project development process. In practice, a majority of renewable energy projects initiated after the CDM has come into operation and have no donor funding in pipeline may fall in the category of the CDM project with some justification by the host governments.

For a specific project activity, the Marrakesh document specifies three baseline approaches. These were listed in chapter 3. In the following, these baseline approaches are discussed with specific reference to the Zafarana project.

- (i) **“Existing actual or historical emissions, as applicable”**: Since there is no indication as to what “historical emissions” should be interpreted to mean, practically all existing emission sources can be considered. Thus, in case of the Zafarana wind plant, emissions from all plants operating in the Egyptian power systems could be considered. It is obvious that this approach assumes that the new power plant would replace average emissions of the entire power system in a country. In the current case it means that the electricity dispatched by the Zafarana wind farm replaces average emissions of the entire Egyptian power system. Therefore, average emissions per unit of electricity (t CO₂/GWh) of the entire electricity system (all plants and fuels) in Egypt were used in calculating the emissions savings in this case.

This method places much emphasis on the past but neglects recent trends that may be more relevant in the context of likely additions to the grid in absence of the proposed wind farm. In countries where past emissions have been high (i.e., plants used carbon intensive fuels and were inefficient), this approach would yield relatively higher emissions savings from the proposed plant. Conversely, if the past emissions were low (i.e., plants used low carbon or non-carbon fuels, and were relatively efficient), it would yield relatively lower emissions savings.

Egypt has a mix of 79% thermal plants and 21% hydro power plants.³⁹ Some wind energy plants have now been commissioned but there was no electricity generation from these plants in 1999-2000 (the year for which data was available from Egypt, and used in this study). Most of the thermal plants operate on a mix of natural gas (NG) and heavy fuel oil (HFO). Assuming that relevant historical emissions are from thermal plants only, a variation of the above approach that considered “all plants excluding renewable (hydro) plants” was also computed. It seems plausible that the qualifier “as applicable” justifies this procedure.

- (ii) ***“Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment”***: This approach focuses on the emissions from recently added plants and expected future trends. It is based on the view that investments in specific energy technologies in a country reflect their respective economic attractiveness. In most cases, this approach may be similar to the “technology on the margin” approach found in the literature on baselines, i.e. the technology last employed or employed for the last few plants. However, in many cases investments in several technologies (e.g., hydro, gas, coal, and wind based plants) may be made simultaneously in a country. In such cases, it may be difficult to identify a specific technology and to decide what constitutes an “economically attractive course of action.”

In the case of Egypt, national experts identified natural gas (which is used to fuel boilers running steam turbines) as the economically attractive technology that is likely to be employed in the future.⁴⁰ Accordingly, this choice was used in calculating one of the baselines.

In case more than one technology (e.g., coal in addition to natural gas) would constitute an economically attractive course of action, it might seem necessary to consider a mix of technologies. This would be even more challenging if renewables, such as hydropower, were among the attractive technologies.

- (iii) ***“The average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 per cent of their category”***: This approach seems to refer to what is discussed under “recent additions“ in the baseline literature. However, recent additions vary depending on how it is interpreted. Some of the possibilities in case of an on-grid renewables project may include the following five options;

³⁹ <http://www.eia.doe.gov/emeu/cabs/egypt.html>

⁴⁰ NREA/Risø National Laboratory, “Pre-feasibility Study for a Pilot CDM Project for a Wind Farm in Egypt” (December 2000: ENG2-CT1999-0001, preliminary draft), p. 45.

(a). **All fuels:** In this approach, average emissions from the previous five years of additions of all type of power plants to the electricity system are estimated. Recent additions indicate the trend and, hence, may reasonably approximate the plant that would be replaced by the renewable plant.

(b). **All fuels but renewables:** Some analysts suggest to exclude renewables from recent additions in order to account for those power systems that have a disproportionate share of renewables in the system, and also to avoid punishing those who took early action to adopt renewable. It can be argued that this interpretation may be acceptable and should even be adopted by the CDM executive board.

(c). **Fuel specific:** In this approach, average emissions of the last five years of additions of fuel-specific plants to the grid are estimated. HFO/NG and LFO/NG based plant were the main additions to the grid in the Egypt over last five years. Therefore recent additions based on HFO/NG and LFO/NG (both separately) were considered for the baseline.

(d). **Base load plants only:** In this approach, the average emissions of recently added base load plants would be used to set a baseline. Thus, in the present case, this approach would assume that the electricity generated by the wind plant replaces electricity generated by base load plants, and the baseline would reflect average emissions of recently added base-load plants. But since it is unlikely that wind energy would displace low-cost, must-run base-load plants, this approach is not followed here.

(e) **Peak plants only:** The approach follows from the opposite assumption, namely that the new plant only replaces peak load plants. But, as documented in chapter 5, this is equally unlikely to be true in the case of a wind farm. Consequently, it was not estimated in this study.

At this early stage of the international regulatory process, it is difficult to predict which of the above interpretations of “recent additions in the past five years” will be acceptable and will be included in the final CDM guidelines.

Next, the various baselines for the Zafarana project listed above, excluding (iii) (d) and (e), were calculated. These approaches can all be expected to approximate the emission savings achieved, i.e., the amount of CO₂ that the 60 MW wind plant in Zafarana would reduce. It is obvious that due to its peculiar electricity generation characteristics and due to the size of the plant, it is not possible to identify one specific existing or future plant that would be replaced by the wind farm. Hence, a range of estimates, based on various approaches, is necessary. Yet, as long as we know how much power the plant would generate and dispatch, the amount of power that would be replaced is certain. This information has been obtained from a wind atlas of the region and from the wind farm’s technical parameters. If there are no grid bottlenecks, all the power generated by the wind farm can be evacuated.⁴¹ Based on the relevant parameters, it was estimated that the 60 MW wind plant in Zafarana would annually replace 268 GWh, including auxiliary losses.⁴²

⁴¹ Evacuation refers to transmitting the power generated for further usage.

⁴² See note (a), Table 1.

For all cases, it needs to be ensured that their performance is among the top 20 per cent in their category. One option is to categorize the plants based on their fuel usage. A list of all the power plants in Egypt is included in Annex 1 (Table 22). The following plant categories can be distinguished:

- plants using HFO/NG as fuel;
- plants using NG as fuel (LFO/NG plants only use NG since LFO use is negligible in Egypt);
- plants using only HFO as a fuel; and
- plants using renewable energy sources (mainly hydro power).

To simplify, and also because it seemed clear from a cursory observation that efficiency differences (indicated by gram of HFO/NG consumed/KWh) did not correlate well with the type of fuel used, only two categories are considered in this study. These are:

- plants using oil (HFO, LFO) or gas (NG) or a mix of oil and gas (HFO/NG, LFO/NG, or HFO/LFO/NG) as fuel; and
- plants using renewable (mainly hydro).

A list of top 20 per cent plants (least consumption of fuel/GWh) in Egypt using oil and gas fuels is included in Annex 1 (Table 23). The list has been used to select the plants for estimating average emissions for the last five years' additions for the baselines (iii) (a)-(c) above.

The CO₂ emission reductions from the Zafarana plant according to the various baseline approaches are included in Annex 1 (Tables 24-29). The results are summarized in Table 1.

Table 1: Baseline emissions for Zafarana 60 MW wind farm project.

| Baseline type | CO ₂ emissions | | Total CO ₂ (1000 tons) | |
|--|---------------------------|-----------------------------------|-----------------------------------|-------------------------|
| | tCO ₂ /GWh | tCO ₂ /yr ^a | Crediting period 10 yrs | Crediting period 20 yrs |
| Historical/all plants | 549.6 | 147,513 | 1,475 | 2,950 |
| Historical/all plants except renewable (hydro) | 686.8 | 184,337 | 1,843 | 3,687 |
| Last five years of additions/all fuels (top 20%) | 593.6 | 159,322 | 1,593 | 3,186 |
| Last five years of additions/all fuels excluding renewable (top 20%) | 632.9 | 169,870 | 1,699 | 3,397 |
| Last five years of additions/LFO/NG plants only (top 20%) | 583 | 156,477 | 1,565 | 3,130 |
| Last five years of additions/ HFO/NG plants only (top 20%) | 663.7 | 178,137 | 1,781 | 3,563 |
| Economically attractive option/NG Plant ^b | 676.1 ^c | 181,465 | 1,815 | 3,629 |

^a Egyptian experts recently estimated the net annual energy production from the Zafarana wind farm to 266 GWh. See NREA/Risø National Laboratory, "Pre-Feasibility Study for a Pilot CDM Project for a Wind Farm in Egypt" (October 2001: Report ENG2-CT1999-001), p. 7. At an assumed availability of 97%, this will replace a gross production of 1.04*266GWh*0.97 = 268 GWh in the system (4% accounts for auxiliary and other losses).

^b NG used in a boiler for a steam turbine plant. Egyptian experts have suggested this as the preferred option in Egypt.

^c Based on Egyptian fuel consumption data, CO₂ emissions have been calculated as follows:

Unit fuel consumption in g/KWh times net cal. value of fuel times carbon emission factor times fraction of C oxidized (223*54.32*15.3*0.995/1000*44/12=676.1).

The implications of the choice of crediting period are also estimated (section 2.2). As mentioned earlier, in the case of the “3*7 years option”, the baseline may be reviewed after each seven-year period. However, to simplify, it is assumed that the baseline does not change. The emission reductions by the Zafarana wind plant have been calculated for the entire project life of 20 years.

The amounts of CO₂ saved over 10 years vary from 1,475,000 tons to 1,843,000 tons. This is a difference of about 25 per cent. Obviously, if the crediting period is increased from 10 years to 20 years, the amount of emission reductions increases two-fold.

4.1 CER Revenues

How much revenue should a host country, or an investor, expect to earn from the sale of the CERs generated by the Zafarana wind farm? Not only is the level of CO₂ emission reductions uncertain (due to the uncertainty of the baseline) but also the price at which the CERs could be sold is uncertain.

CER price estimates have ranged from a “low” of US\$ 0.8 to a “high” of \$ 50 per ton of CO₂.⁴³ The U.S. withdrawal from the Kyoto Protocol in March 2001 has been a major setback for the CDM. The U.S. withdrawal has weakened the market for the CDM considerably, since it was expected that the U.S. would account for some 40 per cent or more of the total Kyoto market for emission reductions. The Prototype Carbon Fund (PCF) of the World Bank had during the 1998-2000 period targeted a price of about US\$ 20/tC (\$ 5.4/tCO₂) and it had made several trades in the range of US \$3 to \$4 per ton of CO₂. The weakening of the market is reflected in the expected price of CO₂ trades. The PCF currently expects offsets to be sold at a price between 0-4 \$/tCO₂.

The implications of the different baselines and of a medium-low price of \$2 and a high price of \$10 per ton of CO₂ are presented in Table 2. For the 10-year crediting period, the revenue realization ranges from 3-18.4 million dollars. For a 20-year crediting period, the range is, obviously, the double of that. Although some of the difference in revenue realization is attributed to different baseline approaches, the five-fold increase in the CER price has major CER revenue implications. With a 10% discount rate, the range is from 1.8 million dollars to 11.2 million dollars for the crediting period of 10 years. It can be seen that baseline approaches alone can make a difference of about 25 per cent in revenue realization (which ranges from 2.95 to 3.69 at \$2 per ton). The highest difference of 25 percent occurs between two approaches that consider

⁴³ During panel discussions at the "Special Financing Session" of the 7th European Roundtable on Cleaner Production, held in Lund, Sweden, on 2-4 May 2001, a representative of the Business Council for Sustainable Development indicated that the industry expects to pay a price between US \$3 to \$5 per ton of carbon. The CO₂ price of \$50 corresponds to a situation where it only is possible to use 15% of the emissions trading potential (because of several issues related to the CDM, such as supplementarity constraints, additionality issues, high transaction costs and so on) through the CDM route, and non-Annex B are able to get a cartel price. This reflects an upper range of possible benefits to non-Annex B from the CDM. A number of modeling studies of the impact of Kyoto on Annex B countries are included in *The Energy Journal* (1999), Special Issue, "The Costs of the Kyoto Protocol: A Multi-Model Evaluation". Most of the studies simulated Annex B emissions trading scenarios and the highest cost indicated was \$209/ton C (Oxford model). Only two studies included CDM in the analysis and indicated carbon prices at \$79 (MS-MRT model) and \$116 (MERGE model) per ton. It should be noted that these prices were based on macro-economic costs of reductions at home. See J.P. Painuly, "The Kyoto Protocol, Emissions Trading and the CDM: An Analysis from Developing Countries Perspective", *Energy Journal* 22(3), (2001).

historical/all plants, one with hydro included, and the other hydro excluded. Similar calculations can be made for the 20-year crediting period and for other discounting rates.⁴⁴

Table 2: Revenue implications of different baseline approaches and CO₂-prices for Zafarana.

| Baseline-type | CO ₂ savings from the CDM project (1,000 tons) | | Revenue at different CO ₂ -prices (mill. US\$) | | | |
|--|---|--------------------------|---|----------|-------------------|----------|
| | 10 year crediting period | 20 year crediting period | 10 year crediting | | 20 year crediting | |
| | | | \$2/ton | \$10/ton | \$2/ton | \$10/ton |
| Historical/all plants | 1,475 | 2,950 | 2,95 | 14,75 | 5,9 | 29,5 |
| Historical/all plants except renewable (hydro) | 1,843 | 3,687 | 3,69 | 18,43 | 7,37 | 36,87 |
| Last five years of additions/all fuels (top 20%) | 1,593 | 3,186 | 3,19 | 15,93 | 6,37 | 31,86 |
| Last five years of additions/all fuels excluding renewable (top 20%) | 1,699 | 3,397 | 3,4 | 16,99 | 6,79 | 33,97 |
| Last five years of additions/LFO/NG plants only (top 20%) | 1,565 | 3,130 | 3,13 | 15,65 | 6,26 | 31,3 |
| Last five years of additions/HFO/NG plants only (top 20%) | 1,781 | 3,563 | 3,56 | 17,81 | 7,13 | 35,63 |
| Economically attractive option/ NG plant | 1,815 | 3,629 | 3,63 | 18,15 | 7,26 | 36,29 |

4.2 Which Baseline to Select?

Since several baselines are possible, project developers need to make a selection and to justify their choice. It should be expected that a developer would select the alternative that is most simple, provides the highest returns, and is easy to justify.

It is clear from Table 2 that the baseline “historical/all plants except hydro” provides the highest revenue earnings, followed by the “economically attractive option/NG plant” option. Various variations of “recent additions” rank below “commercially attractive option,” but above “historical/all plants”, which provides the lowest revenue earnings. This is due to the inclusion of renewables plants in the “all plants” category. The ranking of the alternatives may vary depending on the mix of the plants and their vintage. Thus, a baseline following the “recent additions” approach may be attractive if renewables were predominant in the past but thermal resources were added more recently. Not that some of these options may not be acceptable after more well-specified baseline approaches have been determined by the CDM executive board.

In the initial stage of a CDM project, it may be best if the project developer makes an inventory of all the possible baselines that meet the guidelines and specified criteria. An elementary check can indicate relative attractiveness of each baseline. The proposed baseline for the project can be selected depending on availability of expertise and data, expected level of return, and cost. As far as the crediting period is concerned, a longer time horizon (of 20 years) looks attractive. In

⁴⁴ The discount factors for discounting rates of 5% and 10% for a 20-year lifetime are 0.62 and 0.43, respectively. For a 10-year lifetime, discount factors are 0.77 and 0.61, respectively.

reality, the option would depend on factors such as life-time of the project, perceived risk and complexity in updating the baseline, and the revenue sharing arrangement with the host.

4.3 Conclusions

The Marrakesh Accords reached at COP-7 removed some of the uncertainty surrounding the CDM and proposed some broad principles for baseline development. The CDM executive board is charged with the further development of detailed guidelines for the future. The approaches identified to date include historical emissions, emissions from recent plants, and the economically attractive option. In the case of Zafarana, seven different baselines are possible when applying these approaches. When choosing among the various approaches, it is important that the project developer takes into account the level of complexity, conservatism (that is, in uncertain situations one underestimates the baseline in order to preserve the environment), availability of data, expected return, transaction costs, and available expertise for setting the baseline.

5. PROJECT-SPECIFIC BASELINES FOR ZAFARANA

5.1 Introduction

This chapter outlines a method for estimating the annual CO₂ emission reductions achieved by CDM supply-side projects in the electric power sector. The method may be applied at different levels of detail. The focus is on electricity generation from renewables, particularly on integrating wind power projects into larger power systems. Based on fuel type and fuel conversion efficiencies of individual plants, the CO₂ reduction effects in the overall system due to the project are quantified.

To quantify the CO₂ reduction, the following key questions should be addressed:

- Which power plants (existing and future) in the overall system configuration reduce production due to the renewables project?
- Which fuels and amounts of fuels are substituted at the affected power plants during the period analyzed relative to a reference case or a baseline?

For larger power systems such estimation and system analysis may be very data intensive and may require considerable computational effort. The method described and demonstrated in this chapter aims to limit data needs to the key data for each of the plants in the overall power system and for the specific renewables project in question. The method uses statistical data and system development plans that can be expected to be available in most cases.⁴⁵

5.2 Static and Dynamic Baselines

The method is applied in two baseline studies. Both focus on the same wind power CDM-project. The studies differ with respect to the detail or accuracy of the CO₂ reduction estimation, the data required, and the computational needs.

The first study relies on recent statistical data only:

- Static baseline study: This baseline assumes the present power system configuration, and its mode of operation, as a fixed reference system.

The second and more detailed study takes into account power system developments during the period analyzed:

- Dynamic baseline study: This baseline includes assumptions about baseline system developments during the period analyzed.

The ES³-model developed at Risø National Laboratory simulated the power system (at aggregated level of detail in one-hour time steps) in both baselines.⁴⁶

⁴⁵ Note that official expansion plans may not be available in developing countries where the energy sector is privatized.

⁴⁶ Demonstration and Development of Technology and Planning in the Wind Energy Sector in Egypt. Phase II. 1997; Nielsen, L.H.; Morthorst, P.E. (eds.), *Fluktuerende vedvarende energi i el- og varmforsyningen – det mellemlange sigt. (System integration of wind power on liberalised electricity market conditions. Medium term aspects (In Danish))*. ISBN 87-550-2396-7. ISSN 0106-2840. Risø-R-1055(DA) (April 1998) 154p; Nielsen, L.H. (ed.), *Vedvarende energi i stor skala til el- og varmeproduktion. Indpasning i*

Results from a static baseline study constitute an uncertain basis for evaluating future CO₂ emission reductions and expected CER income generated by CDM projects. The dynamic baseline study aims to reduce such uncertainty but requires further data and more computational effort. Thus, the analysis takes into account forecasts for the development of electricity demand and development plans and forecasts for the supply system (e.g. on commissioning and decommissioning of plants).

The results of the two baselines are compared and discussed. The analysis documents, among other things, the shortcomings of assigning amounts of CO₂ emission reductions to individual renewables projects without taking into account the cumulative system effects created by CDM projects.

5.3 Baseline Studies on the Egyptian Power System

Studies of the Egyptian power system have been carried out in order to compare the consequences of following static and dynamic approaches to baseline development. The CO₂ emission reductions as a consequence of integrating wind power generation in the Egyptian power system is estimated relative to:

- A static baseline defined as the Egyptian power system ultimo year 1999.
- A dynamic baseline defined for the period from 1999 to 2010. Detailed analyses are only made for 1999 and 2010. The baseline for the intermediate period is constructed by a straight line between the emission factors for 2001 and 2010.

The main assumptions about the Egyptian power system in 1999 and in 2010 are presented in Table 3.⁴⁷

elsystemet af vedvarende energi i stor skala i en usikker fremtid. Hovedrapport. (Renewable energy for large-scale power and heat production in the future Danish energy system, main report (In Danish)). ISBN 87-550-2029-1, ISBN 87-550-2087-9(KPL). ISSN 0106-2840. Risø-R-784(DA)(1994) 114 p.

⁴⁷ The data are from Demonstration and Development of Technology and Planning in the Wind Energy Sector in Egypt. Phase II. 1997.

Table 3: Main assumptions in the case studies of the Egyptian power system.

| Egypt | | |
|--|----------------|----------------|
| Power system analysed: | 1999/00 | 2010 |
| Total electricity generation: | 73310 GWh | 125611 GWh |
| New thermal production capacity since 1999/00: | | 9-10.000 MW |
| Electricity demand profile: | 1992 profile | 1992 profile |
| Hydro power: | 14659 GWh/year | 14659 GWh/year |
| Wind power: | | |
| Wind gen. profile | Data from 1992 | Data from 1992 |
| | Case 1: | Case 3: |
| Capacity | 60 MW | 60 MW |
| Electricity gen. to grid: | 257 GWh/year | 257 GWh/year |
| | Case 2: | Case 4: |
| Capacity | 600 MW | 600 MW |
| Electricity gen. to grid: | 2566 GWh/year | 2566 GWh/year |
| | - | Case 5: |
| Capacity | - | 2000 MW |
| Electricity gen. to grid: | - | 8552 GWh/year |

It can be seen from Table 3 that a substantial increase in electricity demand in Egypt is expected by 2010. Consequently, a considerable build-up of new power production capacity of about 9-10 GW is planned for the period analyzed.⁴⁸ This analysis assumes that the capacity of hydropower does not change.

The wind power generation profile (in one-hour time steps) is important for estimating the CO₂ reduction effects in the system. The interplay between the electricity demand profile and the wind power generation profile is essential for the estimation of at which plants, and in which amounts, electricity substitution takes place. Based on this information and the characteristics of the individual plants, the amount of CO₂ emission reductions is calculated.

The key data on power plants in the Egyptian power system and the assumptions made are presented in sections 5.4 and 5.5 focusing on the 1999 and 2010 system configurations, respectively. The details of the method are described in section 5.4.

5.4 Static Baseline Study

The aim in this section is to determine the CO₂ emission reductions associated with integrating wind power in the Egyptian electricity supply system relative to a static baseline. The Egyptian electricity demand profile and electricity supply system in 1999 constitute the static baseline situation for the analysis. CO₂ emission reductions in the supply system are distributed over many power plants, due to modified capacity factors for a number of power plants (relative to the baseline) as a consequence of the wind power integrated.

To illustrate the effects of scale, two cases are examined:

⁴⁸ See GEF, "Proposed Program Concept and Request for a PDF Block B Grant" (April 12, 2001), p. 4. http://www.gefweb.org/Projects/Pipeline/Pipeline_7/Egypt_Private_Sector.pdf

- One case covers the integration of a 60 MW wind farm at Zafarana, Egypt. The generation from this wind farm covers about 0.35 % of the electricity demand in 1999.
- The second case assumes a 10-fold larger project, i.e., a 600 MW wind power plant, in the Egyptian system. The turbine characteristics and the wind regime data are assumed to be similar to the Zafarana project conditions. The 600 MW case wind power thus generates about 3.5% of the total electricity demand in the base year.

The Egyptian peak power demand in 1999 is about 11.7 GW in the overall system. These two cases are analyzed in order to illustrate the sensitivity of the specific CO₂ reduction per kWh wind electricity generated to the installed wind power capacity in the system. Each analysis is carried out as a difference analysis where the alternative system, including the wind power project, is compared to the baseline.

5.5 Wind Power Integration and CO₂ Reduction Approach

Wind power production must be absorbed and consumed in the power system when it becomes available. The wind resources utilized determine its availability. Wind power has limited regulation capability and regulating down the wind power production means reduced or lost production and reduced sales.

When wind power capacity in the system increases the residual part of the supply system must regulate down the production accordingly to give room for the increasing wind power production. Hydropower that often has excellent regulation capability, in particularly at lower time scales (minutes and hours), will contribute short notice regulation in the system. The annual hydropower production is, however, unchanged. As in the case of wind power, the marginal production cost of hydropower may be close to zero, and the CO₂ characteristics of hydropower are attractive. Thus, thermal power production in the Egyptian system is substituted as wind power production increases relative to the baseline situation.

Substitution of fuels and CO₂ reduction at thermal plants depend on the time scheduling (the dispatch or merit order for power generation) of the thermal plants in the spectrum from base load to peak load. The key issues in the analysis are to estimate which plants, or categories of plants, that reduce (or change) production relative to the baseline system operation as a consequence of the wind power generation, and to estimate the associated reductions in the consumption of fossil fuels.

The method divides the analysis into two parts, dealing with the demand side and the supply side aspects, respectively:

- *Part 1: Determines modified load conditions for power plants (with regulation capability, e.g., plants based on fossil fuels).*

The first part of the analysis focuses on the profile (and variation) in the residual electricity demand “after wind power” production. In the alternative, which includes the wind power project, the modified demand profile “after wind power” is to be covered by hydropower and thermal plants. The demand profile modified (and reduced) by the production from 60 MW (and later 600 MW) installed wind power capacity is compared to the initial baseline demand profile. The main result of this analysis is the distribution of substituted production (by wind power) in the spectrum from base load to peak load. This analysis is carried out in one-hour time steps covering one year, the base year 1999.

- *Part 2: Determines modified supply from power plants based on fossil fuels.*
In the second part of the analysis, the merit order of thermal plants and hydropower in the system is addressed. Data estimates for this part of the analysis are derived from the production statistics for 1999 for the individual plants in the Egyptian power supply. An approximated dispatch order in the baseline situation is estimated. It is assumed that thermal plants are operated in the corresponding merit order in the alternative (“with wind power”) situation.

The first part of the analysis is addressed in sections 5.7 and 5.8. The second part is addressed in section 5.9.

Based on the estimated order of dispatch for the thermal plants in the baseline the expected electricity substitution split on individual plants can be determined. From the resulting changes in production at the individual plants, and from data available on the energy average conversion efficiencies at plants and type of fuel used, the CO₂ reduction due to wind power is determined. The results from the static baseline study are presented in section 5.10.

5.6 Basic Assumptions

A number of assumptions have been made in order to reduce the computational work in the analyses. Another reason has been the data available for the analysis.

For the electricity demand and supply in the static baseline the following main assumptions have been made:

- The Egyptian system configuration in 1999 has been chosen as baseline. Statistics on the capacity, annual electricity production, annual fuel consumption, and type of fuel of the individual plants are used in the analysis. The data have been provided by NREA and EEA, Egypt, and are found in Annex 1.
- The overall electricity demand profile for Egypt in one-hour resolution covering one year is based on detailed statistics for 1992. It has been assumed that this 1992 profile, scaled according to the electricity demand in 1999, applies to the base year 1999.
- Hydropower production is assumed not to change from the baseline to the alternative situation, and equals the 1999 production. Furthermore, it is assumed that the hydropower production profile in one-hour resolution is fixed. This profile is based on statistics from 1992.

The following additional assumptions have been made concerning the alternative situation:

- The wind power production profile is based on wind speed measurements at the Zafarana site carried out in 1993. Further details are given in section 5.7.
- The power system is assumed to have no constraints or “bottlenecks” in the grid for the energy flow from production to consumption.
- Scheduling of thermal production plants is based on 1999 statistics. Further details are described below.
- Thermal plants fueled by heavy fuel oil and hydropower are assumed to operate in the base load area.

A more comprehensive analysis may take into account details of individual plants on the fuel conversion efficiency due to changed mode of operation relative to the reference situation. The

analysis assumes that fuel conversion efficiencies and the fuel mix at the individual plants are unchanged and identical to the annual average performance data (based on statistics).

5.7 Electricity Demand, Hydro- and Wind Power Profiles

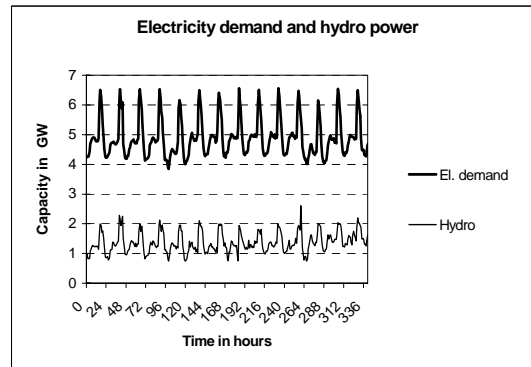
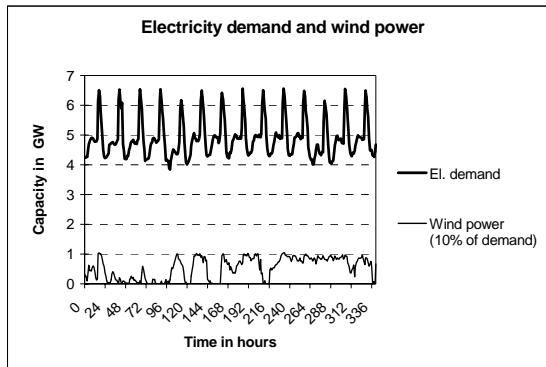
Figure 5 and Figure 6 show sequences of the assumed electricity demand, hydropower production, and wind power production profiles.

Scaled corresponding profiles are used in the present analysis for 1999. The scaled profiles describe details for the 1999 electricity demand, hydropower production, and the expected wind power generation from 60 MW and 600 MW of installed wind power capacity.

The wind power production profile is based on wind speed measurements carried out in Zafarana in 1993 and on power curve assumptions for selected wind turbines. Availability, wake losses, and transmission losses are reflected in the wind power production profile as “viewed” from the grid. The geographical distribution of the wind power capacity and power levelling aspects are not taken into account.

Figure 5. Electricity demand profile for Egypt, and an estimated wind power production profile assuming 10% coverage from wind power and Zafarana wind conditions. Demand data from May 1992.

Figure 6. Hydropower production profile in Egypt and the synchronous electricity demand profile. Data from May 1992 (covering the hours 3100 to 3441).



As already mentioned, it is assumed that the overall hydropower production profile for 1999 (the estimate is based on the 1992 hydropower production) is a similar in the alternative and in the baselines. This is because of the constraints for the hydropower production due to water flow planning of the Nile, which has implication for Egyptian agriculture and irrigation needs.

A sequence of the power demand and the synchronous hydropower production in 1992 is shown in Figure 6. As can be seen from the figure, hydropower contributes much to the power regulation and the peak power supply in the Egyptian system.

5.8 Wind Power and Substitution of Thermal Power

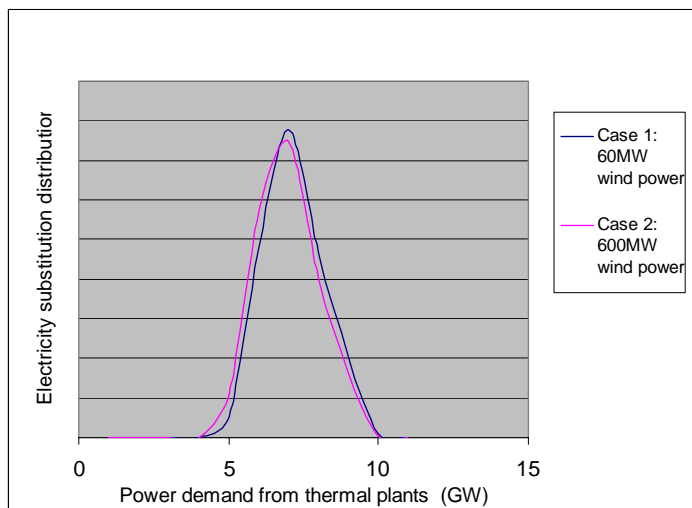
The size (or level) of the electricity demand at the hour in which wind power is generated is important for determining reduction effects in the system. If wind power is generated in the peak load periods, it may substitute production at the peak load plants. Wind power generated in the off-peak periods may substitute production at plants intended for medium load operation.

Peak load plants are intended for operation in relatively few hours of the year to cover the “spikes” or peak loads and are optimized for this purpose. Plants with relatively low investment costs and relatively high operation costs often cover this power demand interval. The opposite is generally the case in the base load area. Relatively low operation costs, primarily because of high energy efficiency in the electricity generation, are important as these plants are intended to operate at maximum capacity almost the entire year. The only exceptions are periods planned for maintenance.

The scheduling of plants in the power supply is important for minimizing production costs. Base load plants have first priority for generation, whereas peak load plants with high operation costs are dispatched last.

Figure 7 shows which thermal power supply levels are modified by introducing wind power in the Egyptian power system. More precisely, Figure 7 shows at which electricity demand levels the electricity substitution would occur. Thermal plants scheduled for operation at these demand levels must expect to reduce their production due to the wind power production.

Figure 7: Distribution of wind power over thermal power demand levels. 1999/2000.



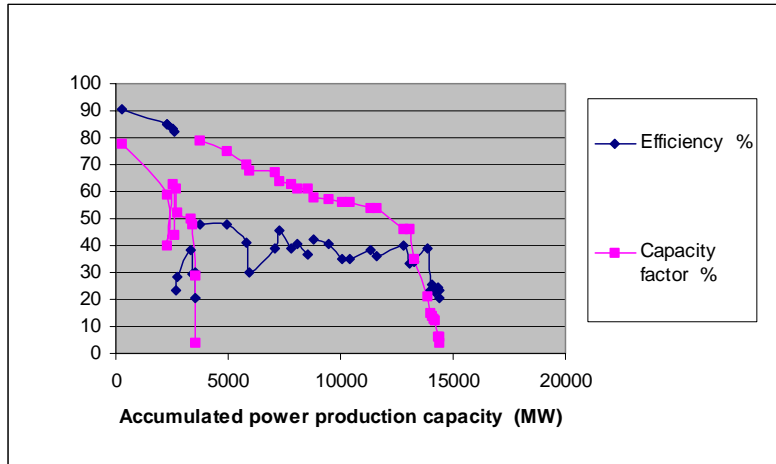
It can be seen from Figure 7 that the electricity substitution would occur at lower capacity levels in the case of 600 MW wind power installed than in the 60 MW case. As expected, in the 600 MW case the electricity substitution involves reduced production at thermal plants scheduled for production closer to the base load area than in the 60 MW case. Thus, more thermal plants are influenced by the wind power and would regulate down their production.

5.9 Baseline Electricity Supply System

The approximate dispatch order in the baseline is derived from statistics on the Egyptian power supply in 1999 (see Annex 1). This merit order for increasing and decreasing production at plants in accordance with variations in the electricity demand is assumed to apply for the alternative situation as well. Thus, in the alternative situation the overall system is assumed to operate according to almost the same production plans as in the baseline situation, although the

production from plants in the medium to peak load area may be reduced due to wind power. The approach taken in estimating the dispatch order is illustrated in Figure 8.

Figure 8: Estimated overall scheduling of power plants in Egypt as based on the capacity factors of individual plants. Plants of descending capacity factor are plotted against the accumulated power production capacity (along the x-axis). 1999/2000.



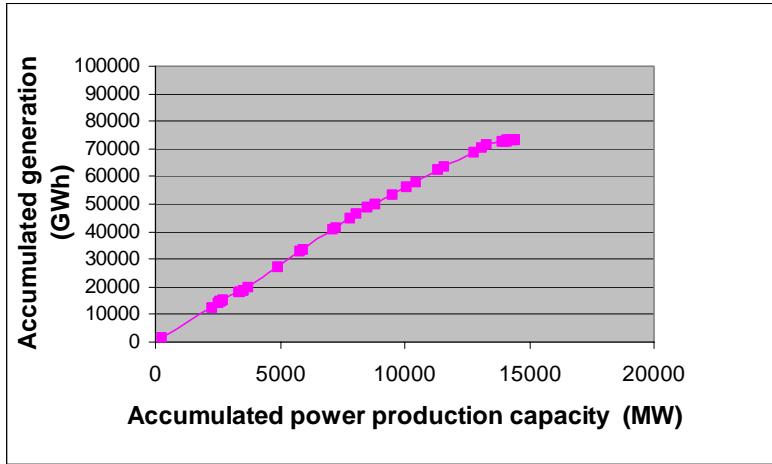
In Figure 8 the capacity factors of the individual plants are plotted in descending order against the corresponding accumulated installed capacity. The total installed production capacity is almost 15 GW.

As already mentioned, hydropower plants and thermal plants using heavy fuel oil are assumed to operate in the base load area. In Figure 8 these plants are therefore situated to the left—in the base load area. All remaining production capacity in the baseline is thermal plants. These thermal plants are sorted according to their capacity factor as of 1999. Low capacity factors characterize plants operating in the peak load area, whereas high capacity factors indicate operation in the base load area. Therefore, the shown sequencing of the individual plants indicates the general scheduling of the plants in the spectrum from base load to peak load operation.

Plants identified (or estimated) to operate in the peak load area in the baseline are assumed to maintain this position in the scheduling of plants in the alternative situation. Thus, the merit order for generation in the baseline is assumed to be the similar in the “with wind power” alternative.

Based on this sequencing of the plants, Figure 9 shows the accumulated power generation plotted against the accumulated installed capacity for the base year 1999. The sequencing of plants is based on the assumed merit order for dispatch. The accumulated generation covers the total demand for electricity in Egypt in 1999.

Figure 9: Accumulated electricity production from the individual plants against accumulated installed capacity. 1999/2000.



5.10 CO₂ Reduction by Wind Power in Egypt

Table 4 and Table 5 show the results of the analysis based on the above assumptions about the power system dispatch. These tables show the 60 MW and 600 MW cases of installed wind power capacity.

Table 4: Integration of 60 MW wind power: Potential substitution of thermal power production and CO₂ reduction in the 1999 system. Case 1.

| Electricity supply 1999: | 60MW | | Reference Efficiency average % | Fossil fuel substituted TJ/year | Type of fuel | CO ₂ -emission reduction k.ton/year |
|---|-----------------------|-----------------------|--------------------------------|---------------------------------|--------------|--|
| | Baseline / Reference | Case 1 | | | | |
| Renewables | 52772 TJ/year | 53695 TJ/year | 85 | | | |
| Thermal power supply split on capacity intervals: | | | | | | |
| GW | | | | | | |
| 0-1 | 31534 TJ/year | 31534 TJ/year | 42 | 0 | - | 0 |
| 1-2 | 31534 TJ/year | 31534 TJ/year | 41 | 0 | - | 0 |
| 2-3 | 31534 TJ/year | 31534 TJ/year | 39 | 0 | - | 0 |
| 3-4 | 31534 TJ/year | 31534 TJ/year | 39 | 0 | NG | 0 |
| 4-5 | 31316 TJ/year | 31294 TJ/year | 38 | -60 | NG | -3 |
| 5-6 | 27926 TJ/year | 27703 TJ/year | 39 | -569 | NG | -32 |
| 6-7 | 17105 TJ/year | 16746 TJ/year | 33 | -1073 | NG | -61 |
| 7-8 | 6855 TJ/year | 6637 TJ/year | 35 | -626 | NG | -36 |
| 8-9 | 1768 TJ/year | 1672 TJ/year | 24 | -396 | NG | -23 |
| 9-10 | 25 TJ/year | 20 TJ/year | 21 | -27 | NG | -2 |
| 10-11 | 0 TJ/year | 0 TJ/year | 0 | 0 | | 0 |
| TOTAL | 263902 TJ/year | 263902 TJ/year | | -2750 | | -156 |

Table 5: Integration of 600 MW wind power: Potential substitution of thermal power production and CO₂ reduction in the 1999 system. Case 2.

| Electricity supply 1999: | 600MW | | Reference Efficiency average % | Fossil fuel substituted TJ/year | Type of fuel | CO ₂ -emission reduction k.ton/year | |
|---|-----------------------|-----------------------|--------------------------------|---------------------------------|---------------|--|--------------|
| | Baseline / Reference | Windpower: Case 2 | | | | | Difference |
| Renewables | 52772 TJ/year | 62008 TJ/year | 9236 TJ/year | 85 | | | |
| Thermal power supply split on capacity intervals: | | | | | | | |
| GW | | | | | | | |
| 0-1 | 31534 TJ/year | 31534 TJ/year | 0 TJ/year | 42 | 0 | - | 0 |
| 1-2 | 31534 TJ/year | 31534 TJ/year | 0 TJ/year | 41 | 0 | - | 0 |
| 2-3 | 31534 TJ/year | 31534 TJ/year | 0 TJ/year | 39 | 0 | - | 0 |
| 3-4 | 31534 TJ/year | 31527 TJ/year | -7 TJ/year | 39 | -18 | NG | -1 |
| 4-5 | 31316 TJ/year | 30816 TJ/year | -500 TJ/year | 38 | -1332 | NG | -76 |
| 5-6 | 27926 TJ/year | 25283 TJ/year | -2643 TJ/year | 39 | -6745 | NG | -384 |
| 6-7 | 17105 TJ/year | 13657 TJ/year | -3448 TJ/year | 33 | -10296 | NG | -586 |
| 7-8 | 6855 TJ/year | 4997 TJ/year | -1858 TJ/year | 35 | -5343 | NG | -304 |
| 8-9 | 1768 TJ/year | 1010 TJ/year | -757 TJ/year | 24 | -3138 | NG | -179 |
| 9-10 | 25 TJ/year | 4 TJ/year | -21 TJ/year | 21 | -102 | NG | -6 |
| 10-11 | 0 TJ/year | 0 TJ/year | 0 TJ/year | 0 | 0 | | 0 |
| TOTAL | 263902 TJ/year | 263903 TJ/year | 0 TJ/year | | -26975 | | -1535 |

Table 6: CO₂ reduction in the Egyptian power system as a result of integration of 60 MW and 600 MW wind power.

| CO ₂ -substitution via wind power | Electricity generation substituted TJ/year | Fossil fuel substituted TJ/year | Efficiency average % | CO ₂ -emission reduction k.ton/year | Specific CO ₂ -substitution | | |
|--|--|---------------------------------|----------------------|--|--|-----------------------------------|--------------|
| | | | | | CO ₂ -reduction ton/kW _e .year | CO ₂ -reduction kg/kWh | |
| Egyptian system 99/00 | | | | | | | |
| Technology | | | | | | | |
| Wind power. Case 1: | 60 MW | 923 | 2750 | 33.6 | 156 | 2.61 | 0.610 |
| Wind power. Case 2: | 600 MW | 9236 | 26975 | 34.2 | 1535 | 2.56 | 0.598 |

As seen from Table 6 the specific CO₂ reduction (in kg CO₂ per kWh wind based electricity supplied to the grid) varies only marginally between the 60 MW case and the 10-fold larger 600 MW case.

A decrease in the specific CO₂ reduction could be expected when increasing the wind power capacity because the increased capacity would substitute electricity production generated by plants approaching the base load characteristics of higher efficiency. This is because the type of fuel used is unchanged. As seen from Table 4 and Table 5, natural gas is the only fuel type involved in the two cases.⁴⁹

⁴⁹ Emission factor: 57kg CO₂/GJ.

5.11 Dynamic Baseline Study 1999-2010

The dynamic baseline study takes into account system developments during the period specified for the analysis. Assumptions about the development of electricity demand, details on planned new production capacity, decommissioning of plants, etc. enter the analysis.

The present dynamic baseline study covers the period 1999-2010. However, to reduce the computational work the following approach is used:

- Baseline analyses are carried out for 1999 and 2010 only.
- The baseline for the intermediate period is constructed as a straight line between the emission factors in these two years.

For the 2010 the baseline study is described in section 5.11.1, and the results of the dynamic baseline study are given in section 5.11.2.

5.11.1 Assumptions and Results for 2010

The main assumptions regarding the Egyptian power system in 2010 are shown in Table 3. A number of additional assumptions concerning the configuration and operation of the system have been made:

- The electricity consumption patterns expressed in the shape of the demand profile are assumed to remain unchanged. The increased electricity consumption in 2010 relative to 1999 thus scales up the demand profile without altering the relative shape of the profile.
- Planned commissioning and decommissioning of plants have been taken into account at aggregated level.
- The relative dispatch order for thermal plants existing in the system in 1999 is maintained.
- New thermal plants are assumed to contribute their maximum to the power supply, and are consequently situated in the base load area of the system in 2010.
- It is assumed that the hydropower capacity in the system in 2010 is unchanged relative to the 1999 situation.
- The potential integration of pumped hydropower for load levelling in the system is not taken into account in the analysis of the system in 2010.
- Thermal plants operating in the capacity interval 8-11GW are assumed to use heavy fuel oil (HFO). Natural gas (NG) is used above this interval.

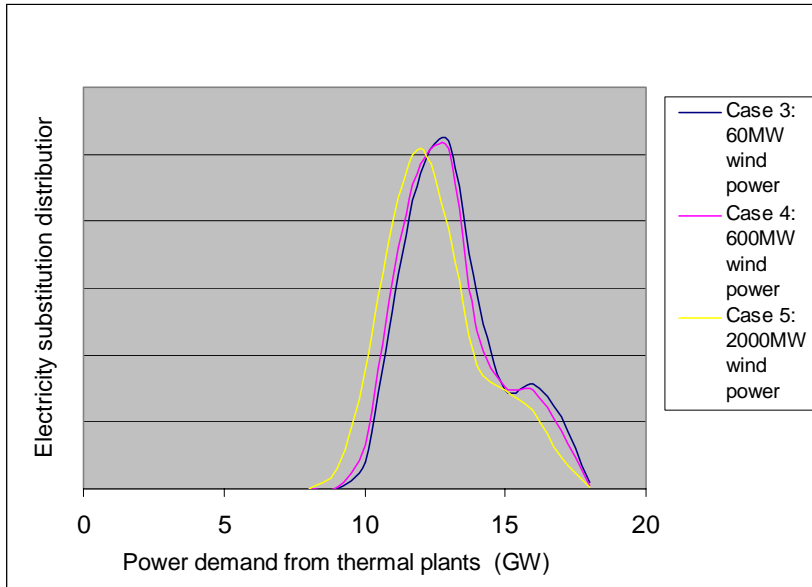
The CO₂ reduction consequence of a wind power project depends on the capacity of wind power that is already present in the system. To illustrate the order of magnitude of this in the Egyptian system in 2010, three cases are analyzed:

- A 60 MW wind farm at Zafarana, Egypt. This generation capacity covers about 0.2 % of the demand in 2010.
- 600 MW wind power in total developed in the system up to 2010. Turbine characteristics and wind regime are assumed to be similar to the Zafarana project conditions. This generation capacity covers about 2.0 % of the demand in 2010.

- 2,000 MW wind power in total developed in the system up to 2010. Turbine characteristics and wind regime assumed to be similar to the Zafarana project conditions. This generation capacity covers about 6.8 % of the demand in 2010.

Figure 10 shows at which levels of thermal power output wind power substitutes thermal production in the three cases.

Figure 10: Distribution of wind power over thermal power demand levels. 2010.



It can be seen from Figure 10 that in 2010 wind power substitutes thermal production at production levels in the interval from about 10 GW to 18 GW. The interval has increased considerable compared to the situation in 1999 where the corresponding interval is about 5-10 GW (see Figure 7). This is due to the expected expansion in electricity demand during the period 1999-2010. An effect of this is that a greater number of thermal plants have modified conditions of operation due to wind power generation compared to the 1999 situation.

The pronounced new and second peak in the distribution shown in Figure 10 is due to increased thermal production in peak hours. As seen from Figure 6, in 1999 the hydropower capacity in the system contributed a large fraction of the peak capacity. However, the increased electricity demand in 2010 and the assumption of unchanged consumption patterns means that thermal plants increasingly enter the peak load area of operation. Thus, more thermal production capacity operates only a few hours a day to serve the peak. This is reflected as the “second top” in Figure 10, which is due to wind power substituting thermal production at high thermal capacity levels. The new plants that have entered the system are expected to have priority for production above the older plants if possible, in order to gain from their improved performance relative to older plants.

It has been assumed that heavy fuel oil (HFO) is substituted in the demand interval 8-11 GW for thermal power. Plants in this interval are assumed to be older thermal plants that initially had base load operation. Due to new thermal plants entering the system during the period up to 2010,

the former base load plants are displaced towards the medium load area in the dispatch assumed for 2010. These plants can use HFO or LFO as fuel, and natural gas is an option for some of the plants. In this analysis it has been assumed that these plants only burn HFO in the 2010 baseline.⁵⁰

Plants operating in the base load area below 8 GW thermal production capacity are not influenced by wind power capacity in the system in the three cases. Thus, wind power does not substitute production and fuel at plants situated in this area during normal operation of the system.

Tables 7-9 show the CO₂ reduction implications of a total capacity of 60 MW, 600 MW, and 2,000 MW wind power. In Table 10, the main results of the three case studies are compared.

Table 7: Integration of 60 MW Wind Power: Substitution of Thermal Power Production and CO₂ Reduction. Case 3.

| Electricity supply 2010 | 60MW | | Reference Efficiency average % | Fossil fuel substituted TJ/year | Type of fuel | CO ₂ -emission reduction k.ton/year |
|---|-----------------------|-----------------------|--------------------------------|---------------------------------|--------------|--|
| | Baseline / Reference | Windpower: Case 3 | | | | |
| Renewables | 52772 TJ/year | 53695 TJ/year | 923 TJ/year | | | |
| Thermal power supply split on capacity intervals: | | | | | | |
| GW | | | | | | |
| 0-..8 | 252269 TJ/year | 252269 TJ/year | 0 TJ/year | - | 0 | - |
| 8-9 | 31526 TJ/year | 31525 TJ/year | -1 TJ/year | 42 | -2 | HFO |
| 9-10 | 31278 TJ/year | 31262 TJ/year | -16 TJ/year | 41 | -39 | HFO |
| 10-11 | 29054 TJ/year | 28931 TJ/year | -122 TJ/year | 39 | -317 | HFO |
| 11-12 | 22839 TJ/year | 22623 TJ/year | -216 TJ/year | 39 | -553 | NG |
| 12-13 | 14652 TJ/year | 14412 TJ/year | -240 TJ/year | 38 | -638 | NG |
| 13-14 | 8143 TJ/year | 8010 TJ/year | -133 TJ/year | 39 | -339 | NG |
| 14-15 | 5444 TJ/year | 5375 TJ/year | -68 TJ/year | 33 | -204 | NG |
| 15-16 | 3235 TJ/year | 3160 TJ/year | -74 TJ/year | 35 | -214 | NG |
| 16-17 | 940 TJ/year | 891 TJ/year | -49 TJ/year | 24 | -205 | NG |
| 17-18 | 21 TJ/year | 18 TJ/year | -3 TJ/year | 21 | -16 | NG |
| TOTAL | 452173 TJ/year | 452172 TJ/year | 0 TJ/year | | -2527 | -151 |

⁵⁰ Emission factor: 78 kg CO₂/GJ.

Table 8: Integration of 600 MW wind power: Substitution of thermal power production and CO₂ reduction in 2010. Case 4.

| Electricity supply 2010 | 600MW | | Reference Efficiency average % | Fossil fuel substituted TJ/year | Type of fuel | CO ₂ -emission reduction k.ton/year |
|---|----------------------|-------------------|--------------------------------|---------------------------------|--------------|--|
| | Baseline / Reference | Windpower: Case 4 | | | | |
| Renewables | 52772 TJ/year | 62008 TJ/year | | | | |
| Thermal power supply split on capacity intervals: | | | | | | |
| GW | | | | | | |
| 0--8 | 252269 TJ/year | 252269 TJ/year | 0 TJ/year | - | 0 | - |
| 8-9 | 31526 TJ/year | 31515 TJ/year | -11 TJ/year | 42 | -27 | HFO |
| 9-10 | 31278 TJ/year | 30971 TJ/year | -307 TJ/year | 41 | -752 | HFO |
| 10-11 | 29054 TJ/year | 27630 TJ/year | -1423 TJ/year | 39 | -3680 | HFO |
| 11-12 | 22839 TJ/year | 20596 TJ/year | -2243 TJ/year | 39 | -5736 | NG |
| 12-13 | 14652 TJ/year | 12300 TJ/year | -2352 TJ/year | 38 | -6264 | NG |
| 13-14 | 8143 TJ/year | 7052 TJ/year | -1092 TJ/year | 39 | -2786 | NG |
| 14-15 | 5444 TJ/year | 4744 TJ/year | -700 TJ/year | 33 | -2090 | NG |
| 15-16 | 3235 TJ/year | 2545 TJ/year | -690 TJ/year | 35 | -1984 | NG |
| 16-17 | 940 TJ/year | 540 TJ/year | -400 TJ/year | 24 | -1658 | NG |
| 17-18 | 21 TJ/year | 5 TJ/year | -16 TJ/year | 21 | -79 | NG |
| TOTAL | 452173 TJ/year | 452173 TJ/year | 0 TJ/year | | -25057 | -1520 |

Table 9 Integration of 2,000 MW wind power: Substitution of thermal power production and CO₂ reduction in 2010. Case 5.

| Electricity supply 2010 | 2000MW | | Reference Efficiency average % | Fossil fuel substituted TJ/year | Type of fuel | CO ₂ -emission reduction k.ton/year |
|---|----------------------|-------------------|--------------------------------|---------------------------------|--------------|--|
| | Baseline / Reference | Windpower: Case 5 | | | | |
| Renewables | 52772 TJ/year | 83559 TJ/year | 30787 TJ/year | | | |
| Thermal power supply split on capacity intervals: | | | | | | |
| GW | | | | | | |
| 0--8 | 252269 TJ/year | 252260 TJ/year | -9 TJ/year | 42 | -21 | HFO |
| 8-9 | 31526 TJ/year | 31064 TJ/year | -462 TJ/year | 42 | -1098 | HFO |
| 9-10 | 31278 TJ/year | 28548 TJ/year | -2730 TJ/year | 41 | -6675 | HFO |
| 10-11 | 29054 TJ/year | 22944 TJ/year | -6110 TJ/year | 39 | -15800 | HFO |
| 11-12 | 22839 TJ/year | 15028 TJ/year | -7811 TJ/year | 39 | -19975 | NG |
| 12-13 | 14652 TJ/year | 8648 TJ/year | -6004 TJ/year | 38 | -15990 | NG |
| 13-14 | 8143 TJ/year | 5277 TJ/year | -2866 TJ/year | 39 | -7315 | NG |
| 14-15 | 5444 TJ/year | 3189 TJ/year | -2254 TJ/year | 33 | -6731 | NG |
| 15-16 | 3235 TJ/year | 1435 TJ/year | -1800 TJ/year | 35 | -5175 | NG |
| 16-17 | 940 TJ/year | 220 TJ/year | -720 TJ/year | 24 | -2983 | NG |
| 17-18 | 21 TJ/year | 2 TJ/year | -19 TJ/year | 21 | -91 | NG |
| TOTAL | 452173 TJ/year | 452175 TJ/year | 2 TJ/year | | -81855 | -5155 |

Table 10 shows that the CO₂ reduction per kWh wind electricity generated increases when the total wind power capacity in the system increases. This is the opposite of the 1999 situation where the CO₂ reduction decreases from the 60 MW case to the 600 MW case. The reason for this is that plants burning heavy fuel oil (HFO) are influenced in the 2010 situation. As wind capacity increases, more substitution of HFO takes place and natural gas (NG) constitutes a decreasing fraction of the total amount of displaced fuel. Despite increased energy-efficiency assumed for plants closer to base load, the shift towards HFO increases the CO₂ reduction.

Table 10: Main results of the estimated CO₂ reduction in 2010 in the Egyptian power system as a result of integration of 60 MW, 600 MW, and 2,000 MW wind power.

| CO2-substitution via wind power Egyptian system 2010 | Electricity generation substituted TJ/year | Fossil fuel substituted TJ/year | Efficiency average % | CO2-emission reduction k.ton/year | Specific CO2-substitution | | |
|---|---|------------------------------------|-------------------------|--------------------------------------|------------------------------|-------------------------|--------------|
| | | | | | CO2-reduction ton/kW_year | CO2-reduction kg/kWh | |
| Technology | | | | | | | |
| Wind power. Case 3: | 60 MW | 923 | 2527 | 36.5 | 151 | 2.52 | 0.590 |
| Wind power. Case 4: | 600 MW | 9236 | 25057 | 36.9 | 1520 | 2.53 | 0.592 |
| Wind power. Case 5: | 2000 MW | 30787 | 81855 | 37.6 | 5155 | 2.58 | 0.603 |

5.11.2 Results of Dynamic Baseline 1999-2010

Compared to the situation in 1999, in 2010 the CO₂ reduction due to the 60 MW wind power project has changed marginally only. The simulation result for 1999 shows a CO₂ reduction of 0.610 kg CO₂/kWh, while the simulation for 2010 shows a CO₂ reduction of 0.590 kg CO₂/kWh, if no further wind power capacity enters the system during the period. If, however, it is assumed that wind power capacity during the period up to 2010 increases to 600 MW, then the CO₂ reduction is slightly higher.

Two opposite effects produce this result. One is that the increased electricity demand has the effect that wind power tends to substitute electricity at plants with relatively higher energy efficiency in the low load periods. On the other hand, this also means that not only NG fired plants are affected. In the low load periods HFO fired plants are increasingly affected, and this increases the CO₂ reduction compared to plants burning NG, if energy efficiencies are the same. Taken together, these effects reduce the CO₂ reduction in 2010 in the 60 MW case relative to the situation in 1999.

In 2010, the CO₂ reduction increases slightly from the 60 MW case to the 600 MW case because more HFO fired plants are affected by the wind power generation. And from the 60 MW case to the 2,000 MW case, the CO₂ reduction increases from 0.590 kg CO₂/kWh_{wind} to 0.603 kg CO₂/kWh_{wind}.

Table 11: Main results of the dynamic baseline study. Estimated average CO₂ reduction in the Egyptian power system in period 1999-2010 as consequence of integration of 60 MW wind power 1999. Zafarana wind conditions assumed.

| CO2-substitution via wind power 1999-2010 Egyptian system 1999-2010 | Year 1999 | | Year 2010 | | Period 1999-2010 |
|--|------------------------|----------------------------------|------------------------|----------------------------------|--|
| | Total capacity Wind | Specific CO2-reduction kg/kWh | Total capacity Wind | Specific CO2-reduction kg/kWh | Average specific CO2-reduction kg/kWh |
| Development in wind capacity assumed | MW | kg/kWh | MW | kg/kWh | kg/kWh |
| Constant 60MW throughout the period 1999-2010 : | 60 | 0.610 | 60 | 0.590 | 0.600 |
| Increase from 60MW --> 600MW during period 1999-2010 : | | | 600 | 0.592 | 0.601 |
| Increase from 60MW ->2000MW during period 1999-2010 : | | | 2000 | 0.603 | 0.606 |

As Table 11 shows, the average CO₂ reduction for the 1999-2010 period due to a 60 MW wind project initiated in 1999 depends on the total deployment of wind power during that period. If the 60 MW wind power in the system is not increased over the period, the average CO₂ reduction is estimated to about 0.600 kg CO₂/kWh_{wind}. If, however, wind capacity in the system increases

during the period to 2,000 MW, the average CO₂ reduction over the period is estimated to be about 0.606 kg CO₂/kWh_{wind}. As illustrated by the baseline studies on wind power, the CO₂ reduction achieved by a CDM project depends on all other concurrent CO₂ reduction projects in the power system. A project alters the CO₂ characteristics of the overall system. In order to estimate CO₂ reduction effects of a project during a CDM period, assumptions about all planned CDM projects to be initiated during the period must be taken into account.

5.12 Comparison of Results from Static and Dynamic Baselines

The data requirements are reduced when using a static baseline approach instead of the more detailed dynamic baseline approach. And, as seen from Table 11, the differences in results are small for the 60 MW Zafarana wind project analyzed. It may be important, however, to take expected system developments into account, including concurrent CDM projects.

Table 11 shows that the CO₂ reduction in the 60 MW case is about 0.610 kg CO₂/kWh_{wind} in the static baseline study and about 0.600 kg CO₂/kWh_{wind} in the dynamic baseline study if no further wind capacity enter the system. The main reason for this is that the increasing electricity demand, and scale-up of the demand profile, has the effect of reducing the capacity factor and the number of operating hours for the peak load plants. Consequently, these plants of relatively low energy-efficiency contribute less to the CO₂-reduction achieved. This effect is reduced in the 600 MW case due to HFO increasingly being substituted later on in the period covered by the dynamic baseline.

In the dynamic baseline study the expected reduction of about 0.600 kg CO₂/kWh_{wind} relates to the situation where no further wind capacity enters the system during the period. However, if a build-up of 2,000 MW wind capacity takes place during the period, the CO₂ reduction by the 60 MW project increases.

More wind capacity entering the system in the period increases the CO₂ reduction for all projects initiated in the period. Thus, in the Egyptian case, the first CDM project may gain from the next being initiated. As mentioned already, this is due to the increasing electricity demand and a gradual change in the fuel substituted from NG towards HFO during the period.

These results obviously depend on the particular system in question. However, they illustrate that power systems based on a mix of fossil fuels may show these characteristics when CO₂-intensive fuels (e.g., coal) predominantly are used by base load plants. The case studies on the static baseline did not illustrate this effect. However, the same characteristics would emerge from a static baseline study when wind capacity is increased and substitution of HFO as well as NG takes place.

This chapter also illustrated the dilemmas that are inherently related to assigning amounts of CO₂ emission reductions to individual renewables projects among a number of projects. Different electricity production profiles of renewables projects (e.g., wind power and photovoltaic) have different CO₂ reduction effects in power systems.

Generally, the effect of a particular renewables project depends on the totality of all renewables projects integrated into the electric system.

6. CARBON FINANCING: THE ZAFARANA EXAMPLE

6.1 Introduction

This chapter is concerned with a key issue for all CDM projects, namely the issue of turning emission reductions into cash flow on a project and perhaps making a project financially viable by selling the emission reductions that it would generate.⁵¹ The financial analysis is made in a spreadsheet-based model, which is specifically developed for the purpose of this analysis. The model enables the financial analysis of a 60 MW wind farm financed according to normal non-recourse (project finance) principles with and without the costs and benefits that would result from the sale of the emission reductions.

The purpose of the financial analysis is not to assess the financial viability of wind energy in Egypt as such, but instead to evaluate the effect of “carbon financing” on the project’s financing and to illustrate the difference that the income from selling CO₂ reductions makes to the project’s financing. The implications of the CDM for the project will be illustrated by describing the differences in the project’s finances resulting from the CDM costs and revenue streams over the project’s life cycle.

This chapter will also highlight the aspects of project financing that are unique to the CDM. It will illustrate the additional and CDM-specific issues that a developer or financier that is comfortable with power projects such as wind parks would need to address in order to turn a business-as-usual project into a CDM project.

There are several perspectives from which to approach the issue of carbon valuation:

- The project developer;
- Equity investors and debt providers;
- The host country (e.g. Egypt);
- Buyers of emission reductions; and
- The United Nations Framework Convention on Climate Change and the Kyoto Protocol, including its CDM.

This analysis will take the perspective of the developer and the investor. More than any other party these are the stakeholders who would determine whether a project would be developed as a CDM project, and who would have an interest in pursuing the CDM project cycle to its completion. The other parties or stakeholders are more involved in setting the rules and framework for CDM projects than getting involved at the level of individual projects. It is within this framework that the project developer must ensure that the project meets all the criteria necessary to be eligible under the CDM and that the procedures for calculating the emission reductions comply with international regulations in this area.

Many variables influence the net cost-benefit effect of selling emission reductions and it is impossible to develop general guidelines and rules of thumb to use for deciding if it worthwhile to pursue the “CDM route” and which of the different CDM rules to use. This analysis is focused

⁵¹ It is important to keep in mind that the models and the assumptions used in the financial analysis are based on information from comparable projects and are only intended to give a representative picture of an actual wind park project of this size and scope in a developing country. The inputs and results are used for illustrative purposes only; they should not be taken as reflecting the actual financial costs and returns of wind farms in Egypt.

on the case of the Zafarana 60 MW wind farm. By using a specific case study, rather than presenting a general discussion, it is possible to achieve a good understanding of what the CDM means in terms of project financing. This analysis will give project developers and investors an idea about what steps they should follow and about some of the decision-making criteria to apply at each step.

Two different valuations of the Zafarana wind park are presented below. The first is a so-called “quick scan” valuation. The second is a quite detailed financial assessment.

6.2 ADDITIONALITY ISSUES

6.2.1 Financial Additionality

The concept of financial additionality in the CDM is based on the assumption that the CER revenues might turn a project that was not financially viable, and therefore would not have been implemented, into a project which is financially viable and that therefore will go ahead. If this is the case the project can be said to be financially additional compared to the business-as-usual situation and that it only happened because of the inclusion of CO₂ financing.

In reality, however, the issue of financial additionality has been shown to be a non-starter for a number of reasons. In many cases (e.g., the Zafarana wind park) the amount of revenues that could be earned by selling CO₂ reductions under current prices is too small relative to the project’s commercial income (from selling power) to either make or break the project. In general, if the project was not viable without CO₂, it would not be viable with CO₂. If, however, a higher price range for CO₂ is realized (such as the US\$10/ton CO₂ example used in this report) carbon financing can turn a marginal project around so that it becomes profitable.

This is not to say that the effect of CO₂ financing is negligible but rather to point out that the criteria of financial additionality is not strictly relevant to a project such as Zafarana. The difference that CDM financing can make by increasing the financial return of the project to the investor(s) is to move the project up on the financier’s priority list and therefore make implementation of the project more likely.

6.2.2 Programme Additionality

Program additionality could be seen as a variant of financial additionality. It is intended to address the cases where governments use existing funds, instead of new or additional funds, to finance CDM projects. One example would be a government that finances CDM projects out of existing Official Development Aid (ODA) funds instead of new or additional public funding. The criteria of programme additionality is therefore intended as a test to be used by host countries to ensure that the normal (without CDM) flow of development aid is not being redirected and channeled into CDM project investments. The project developer has therefore the obligation to indicate to the host country that the CDM financing is additional to existing development aid.

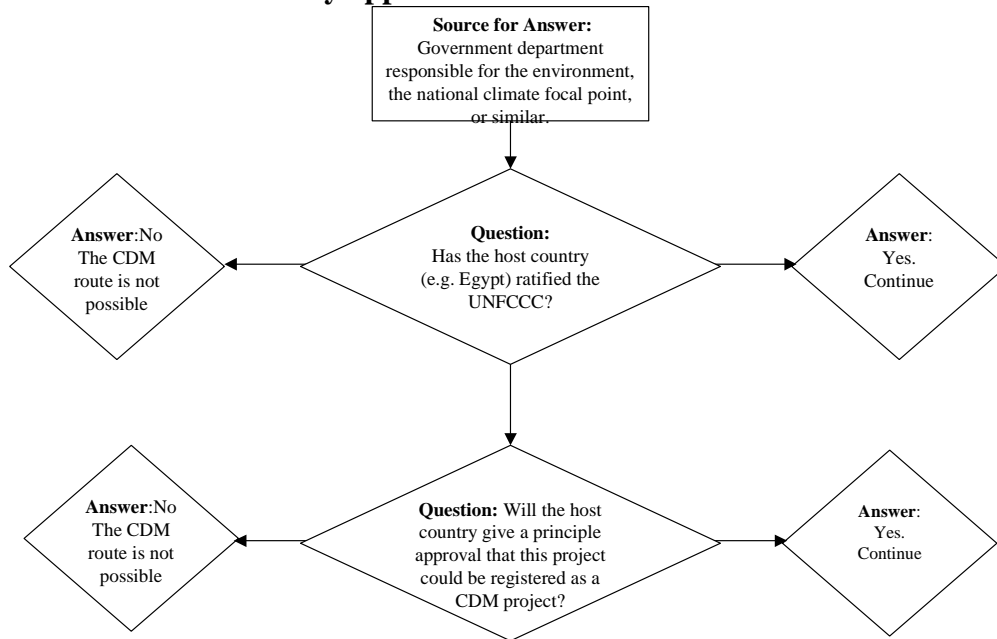
6.3 “Quick Scan” CDM Valuation

The first question that any wind park developer would ask is: Would it be worthwhile to try and turn the project into a CDM project? So before preparing a detailed baseline assessment and CDM analysis, it is worthwhile to do a quick scan, or order of magnitude, analysis of what the CDM can do for a project.

A principle decision about whether to follow the CDM route or not should be made at this point and at low cost (in terms of time and money) to the developer. Despite the CDM criterion of financial additionality (i.e., only those projects that would not have been invested in anyway are financially additional) a key premise is that a project’s basic financial figures should look good. It should be stressed that the CDM will not turn a “bad” project into a “good” project. What it might do, however, is to turn a marginal project into a less marginal or slightly stronger project. One should therefore not attempt to bring CDM financing into the project until in the latter stages of the pre-feasibility study. If the pre-feasibility results are positive, the following approach could be followed to get a sense of the project’s CDM potential.

The following questions should be answered:

1. Host country approval



2. Emission Savings/Baseline

Get an idea of the average kg CO₂/kWh (kilogram of carbon dioxide per kilowatt hour electricity produced) emissions from the local power utility or government agency. A good source for this could be the utility’s annual environmental report or their environmental department. If a CO₂ figure is not readily available, then collect information on the generation mix of all the generators in the relevant grid system: What percentage of electricity in one year was contributed by which fuel

source? An average kWh could be made up of, say, 50% coal, 30% natural gas, and 20% hydro generation. Multiply the percentage share with the internationally agreed standard emission factors for the particular fuel to calculate the kg CO₂/kWh figure.⁵²

3. Emission Savings Value

Multiply the CO₂/kWh figure with the projected annual power production of the wind park to get the annual emission savings.

Use a conservative value of \$/t CO₂ to get an annual value of the emissions savings. At the time of writing this report, the market value is between US \$3-7 per ton of CO₂. More accurate or up-to-date prices can be obtained from the prospective buyer of the CO₂, such as the Prototype Carbon Fund (PCF) of the World Bank, the Dutch government's CERUPT programme, or others.

4. Analysis

- Insert the annual CO₂ revenue into the project's financial model.
- Add the following costs related to turning a project into a CDM:
- Use paid consultants to manage entire CDM process – approximately US\$ 100,000 in Year 0 of the project; or, “do it yourself” – US\$ 50,000 and three man months of professional time.⁵³

From the above analysis it should be possible to get an answer as to the institutional viability of the project (i.e., would it be eligible as a CDM project?) and a ballpark figure for the financial returns that should be expected. This quick assessment figure would be quite close to what one would achieve through a more detailed and comprehensive assessment of baseline emissions, CO₂ values, and costs.

If the outcome of the analysis is favorable, then a decision should be taken whether to use specialized CDM consultants, or to manage the CDM component of the project internally as part of the normal project development process. In either case, a more detailed analysis of the various variables should be completed to get more accurate figures for the baselines, CO₂ values, costs, and host country approval time scales.

6.3.1 Example: Zafarana

This section presents the results of a pre-feasibility study stage assessment of the CDM and its implications for the 60 MW wind farm in Zafarana. The inputs required for this analysis are basic information that would be available during the early stage of project development.

1. Host Country Approval:

- Egypt ratified the UNFCCC on December 5, 1994, and it signed the Kyoto Protocol on March 3, 1999; the Kyoto Protocol is not yet ratified by Egypt.⁵⁴

⁵² The emission values can be obtained from a variety of sources including <http://retscreen.gc.ca>.)

⁵³ These costs are based on quotes received from industry sources presently involved in emission reductions projects.

- Principle approval can be obtained from:
Mr. Ibrahim Abdel Gelil
Executive Chairman of the Egyptian Environmental Affairs Agency
Egyptian Environmental Affairs Agency
30 Misr Helwan Road, El Maadi
El-Mohandeseen/Dokki
11728 Cairo
tel (20-2)352-6481
iagelil@idsc.gov.eg

2. Emission Baseline

Total national electricity generation (1999E): 64.7 billion kWh
Around 79% of Egypt's electric generating capacity is thermal (primarily gas turbines), with the remaining 21% hydroelectric.⁵⁵

Assume that the wind power would replace the marginal power plants (i.e. gas), not the base load hydropower. Each kWh of wind power therefore displaces 1kWh of gas power.

Emission factor (new generation gas turbines): 0.461 t CO₂/MWh.⁵⁶

3. Total emission savings

| | |
|--|--|
| Wind park power production (60 MW at 4,433 full load hours/year) | = 266,000,000 kWh/annum |
| Emission savings | = 266,000 * 0.461 tCO ₂ = 122,626tCO ₂ /annum |
| Over project lifespan (20y) | = 2,452,520 tCO ₂ |
| CO ₂ price @ \$4/t | = \$ 490,504/annum |
| Value over project life span | = \$ 9,810, 080 |

4. Analysis

Using external consultants for the CDM documentary requirements increases development costs in year 0 by \$100,000.

Annual increase in revenue:
Gross income from electricity sales @ \$0.0289/kWh
= 266,000 MWh * \$0.0289
= \$ 7,687,400/annum

Combined gross income (power + CO₂)

⁵⁴ Source: <http://www.highway.idsc.gov.eg/ccinfo/> obtained via <http://www.unfccc.int/text/resource/country/egypt.html>

⁵⁵ Source: <http://www.eia.doe.gov/emeu/cabs/egypt.html>

⁵⁶ Source <http://retscreen.gc.ca>.

= \$ 8,177,904/annum

Increase in annual gross income = 6%

Feeding the CDM income into the project's financial model gives the following results:

Impact on Project IRR = + 1.47%

Impact on Return on Equity = + 4.67%

Based on this fairly conservative “quick scan” assessment, one can conclude that turning this project into a CDM project would increase the benefit (return on equity) to the investors by almost 5%. It is important to note that, while this “quick scan” analysis gives an indication of the additional benefits that the CDM can provide to the project, it does not give any indication of the project's overall financial viability. The income from the CO₂ credits generated is about 6% of the income derived from power sales. In order to be successful, the project must be viable, or at least marginally viable, before the CDM revenue is accounted for. CDM income alone would not be sufficient to make the project viable.⁵⁷

6.4 Detailed CDM Financial Assessment

6.4.1 The Financial Model

The Zafarana wind park's financial viability is calculated by using standard project finance or engineering economic procedures. Due to the widespread use of this analytical approach, it is relatively easy for the project sponsors and specifically for debt providers to evaluate and compare the results with other similar investments. The weakness of this approach, which tends to undervalue some of the benefits of wind power projects, is that it does not include a valuation of the project's relative financial risk compared to the rest of the Egyptian power sector, nor does it compare the relative risk compared to other assets in the shareholders' portfolio. These relative risk values can be determined by using alternative approaches, such as the Capital Asset Pricing Model. But since the objective is to illustrate and compare the “with” and “without CDM” cases, we can suffice with the standard non-recourse project finance model.

A financial model was developed to analyze the financial performance of a hypothetical 60 MW wind farm to be constructed at Zafarana in 2002. The financial model used an annual cash flow projection method to determine a number of indicators of financial performance:

- Project Internal Rate of Return (IRR);
- Return on Equity (RoE);
- Net Present Value (NPV);
- Financial Levelised Cost of Production (FLCP);
- Cost Benefit Ratio;
- Average and minimum Debt Service Cover Ratio (DSCR); and
- Average and minimum Interest Cover Ratios (ICR).

⁵⁷ Other analysts have similarly concluded that CDM projects must begin with a strong financial base, because credits will not be sufficient to make unsound projects commercially viable. See Amy Ellsworth, 'CDM Carbon Pricing in the Renewable Energy Sector: A Market Perspective'. A paper presented at COP-6, November 14, 2000. <http://www.greenpeace.org/~climate/climatecountdown/cdmrenew.pdf>

Financial performance indicators:

Economic Internal Rate of Return (EIRR) was calculated on the gross cash flow (income minus operating expenses but excluding the cost of financing) and the total capital cost of the project.

Economic Net Present Value (ENPV) was calculated on the gross cash flow (income minus operating expenses but excluding the cost of financing), the total capital cost of the project, and a discount rate of 5%. A negative value for the ENPV is the result when the EIRR is less than the discount rate used.

Return on Equity (RoE) after taxes was calculated from the equity investor's perspective. It calculates the return an investor would expect on the equity investment (in this case 35% of total project capital cost) from the net cash flow (income after all costs, taxes, and interest payments).

These indicators were calculated for a reference business-as-usual case (i.e., "without CDM") and for six CDM cases defined by different emission baselines and CO₂-prices.

6.4.2 Financial Modeling Assumptions and Inputs

The inputs to the financial model were taken from data supplied by industry and research organizations, particularly from the EU-financed CDMED project. Care was taken to use as accurate data as possible, but the inputs would remain motivated assumptions and should be treated as such.

The basic inputs and assumptions used in the model include:

- A basic financial structure with 35% equity and 65% concessionary loan (20 years at 3% interest rate with a 5 year grace period);
- The capital costs of the 60 MW wind park are US\$ 64 million;
- Power production is 266,000,000kWh/annum; and
- Power is sold at a fixed tariff price of US\$ 0.0289/kWh.

6.4.3 CER Income Stream Valuation

As mentioned in chapter 2, under the CDM the units of emission reductions that can be bought and sold in the carbon market are referred to as CERs. A CER is equal to one ton of CO₂ equivalent. Reduced emissions of the other greenhouse gasses regulated under the Kyoto Protocol, such as methane and nitrous oxide, can be converted to the amount of CO₂ that would have the equivalent global warming effect.⁵⁸ CERs and ton of CO₂ are the units used in trading. CER value is quoted in US\$/t CO₂ (sometimes in US\$/t C).⁵⁹

There are a number of different options available to determine the monetary value of the emission reductions generated by a project.

⁵⁸ The non-CO₂ gases regulated under the Kyoto Protocol can be converted to CO₂ equivalents by using the Global Warming Potentials, on a 100-year lifetime basis, developed by the IPPC.

⁵⁹ The conversion factor for C to CO₂ is 3.67.

Pre-CDM Market Price

Since the CDM has not yet formally entered into force, there is no clear internationally accepted set of rules under which CER trading can take place. However, due to some early movers, such as the World Bank Prototype Carbon Fund (PCF), the Dutch government's ERUPT and CERUPT programs, and some companies (mostly utilities or oil companies), a nascent market in emission reductions is emerging. These buyers are price setters in the global CO₂ market. Selling the emission reductions from a project in the world market has the benefit of turning CO₂ reductions into actual revenue and doing so today. One downside of entering the pre-CDM market is that there is a possibility that the CO₂ price will rise once the CDM is fully implemented. The old dilemma—Sell today for a certain but low price, or wait for a possible higher (or lower) price to emerge—thus seems equally relevant for the emerging global CO₂ market.

Currently, the average market price of CO₂ is in the range of US\$ 3-7/t CO₂. For the purposes of this project, two market prices—US\$2 and US\$10—are used.

Incremental Value

CO₂ buyers can apply the incremental value approach to projects for which the income from power and energy sales alone is not enough to ensure project viability and an additional income stream (e.g., sales of emission reductions) must be found. The incremental value price of CO₂ is calculated by setting a predetermined internal rate of return or return on equity on the project and then calculating the price per ton CO₂ that is required to achieve these rates of return. The CO₂ price would then vary from project to project and is in general far higher than the market price. Values derived in this way are often quoted as the project's mitigation cost. A good mitigation project would have low costs per ton of CO₂, while a less good project would have high costs per ton of CO₂.

Expected Future CDM Market Price

Various models have been developed to predict the possible CER price ranges that are expected once the CDM has been fully implemented. These models depend heavily upon a number of uncertain variables, such as the participation of the USA in the global carbon offset market and inclusion of carbon sinks. In general, the price will be influenced by the amount and quality (country of origin, standard of verification) of emission reductions offered for sale and the number of buyers and sellers in the market. Under a formal, internationally accepted and working CDM programme the risk level of CERs would be reduced, since buyers of CERs would have more certainty that the CERs can be sold to the next buyer. The lower risk associated with CERs would increase their value.

It is unlikely that the future price of CERs will either increase or drop significantly below the present levels of US\$2-\$10.

6.4.4 CER Ownership

The ownership of the CERs from a project is an important issue to consider. Various parties, including the project developers, investors, debt providers (banks), or the donor country, can and would have reason to try and secure ownership of the CERs. The legal ownership of the CERs will most likely be determined by the financing requirements of the project that is generating the emission reductions. The developer might want to claim a portion of the CERs as compensation

for its development costs. The equity providers would want to claim the CERs by virtue of being the project's main financiers. The ownership of the CERs might lie with the Special Purpose Company (SPC) that is often created to develop and own projects such as Zafarana. The SPC can then sell the CERs to some or all of its financiers or to a third party that is not a direct investor in the project. The legal owner of the CERs is able to claim the CERs resulting from the project and to sell these to a third party. What is important is not so much the ownership of the CERs, but what the revenue stream that results from the sale is used for.

Two basic cases can be considered. If the project is only marginally financially viable and the CER revenues are required in order for the project to meet the financiers hurdle rates of return, the revenues from selling CERs would be viewed as an income to the project. The owner of the CERs can use this contribution of funding to establish or extend its claim on the project's returns. The legal owner of the CERs may be required to transfer the claim on revenues to the project's bank as a security.

In the case where the project is financially viable without the CER revenues the owner of the CERs can sell or retain them according to its own needs. This type of project would not be "financially additional". The ownership of the CERs can then be used either as an offset against own emissions or sold to another party.

6.4.5 CDM Transaction Costs

Extracting carbon value from a project comes at a cost. These costs are additional to the development costs that a "non CDM" wind park would incur. In line with normal development costs the CDM transaction costs are not scale sensitive, i.e., the cost of turning a project into a CDM project remains roughly the same irrespective of the size, or the cost, of the project. For a smaller, lower cost project the transaction costs as a percentage of the overall costs would therefore be higher than for a big project. As mentioned in section 2.5, in order to remove this barrier to small projects, a concessionary set of rules for small projects is likely to be developed under the CDM.

CDM transaction costs are incurred at several steps in the CDM project cycle (section 2.7), and include amongst others:

- Securing host country approval of the project as a CDM project;
- Determining the emission baseline and the projected emission reductions;
- Selecting a suitable international environmental auditing company accredited by the CDM executive board to monitor and verify the project;
- Development of an acceptable monitoring and verification plan;
- Validation of the baseline and the project as such by an international auditing company accredited by the CDM executive board;
- Registering the project with the CDM;
- Meeting the monitoring and verification requirements of each crediting periods;
- Verification by an international environmental auditing company;
- Placement of the emission reductions (CERs) for potential buyers;
- Negotiation with potential buyers; and
- Drawing up the appropriate legal framework for the issuing and selling of the emission reductions.

Meeting these conditions require both costs and time. The costs of hiring a specialized consulting group to manage the CDM component of a project from start to finish is expected to be in the order of \$100,000 depending on factors such as the complexity of the baseline and the monitoring and verification plans.⁶⁰ In the case of Zafarana this is a small amount of money compared to the total project cost and the revenue stream expected from selling emission reductions. The expenses incurred in the CDM process are mostly professional time for baseline development, negotiating with the host country government, and producing the relevant contracts.

What could be of more concern than the actual costs is the possibility for time delays in securing the necessary permits and contracts. Delays in closing the CDM component of a project's financing would delay the closing of financing of the entire project. In general delays are to be expected since neither the host countries, the CDM executive board, nor the buyers of CERs have much experience in conducting such transactions. It is therefore advisable to include a brokerage with experience in CDM type projects on the project team and to commence with the CDM process early on during the project cycle so as to minimize the impact of delays in securing CDM approval.

6.4.6 Crediting Period

Under the CDM rules the emission reductions from a project can be registered and sold in specific intervals or crediting periods. The project developer can choose at which periods this can take place by selecting one of the following crediting periods:

- A single 10 year period; or
- Up to 3 periods each of up to 7 years of duration. This allows for a maximum of 21 years (3 periods * 7 years) or a minimum of 1 year (1 period * 1 year) or any number in between.

At the end of each crediting period the emission reductions must be verified and certified. The verified emission reductions can then be submitted to the CDM executive board for approval and for the issuance of the CERs.

There is still some uncertainty about what monitoring, verification, and certification will entail under the CDM. Once clarified, it will be clear what type of company can certify emission reductions and what the costs of certification will be. As it stands at present, it is likely that the UNFCCC secretariat would issue the certificates.⁶¹

Based on present market rates, a cost of US\$ 25,000 per crediting period was used in the financial models as the cost of issuing a certificate specifying emission reductions achieved.

6.5 Results of Financial Modeling

It is important to keep in mind that the model and the assumptions used for the CDM analysis are for illustrative purposes only and should not be taken as reflecting the actual costs and returns of

⁶⁰ This figure is based on cost estimations received from companies presently involved in offering these services. For an overview of transaction costs, see "Responses by the SSC Panel Related to Its Terms of Reference", <http://unfccc.int/cdm/Panels/ssc/resptor.pdf>.

⁶¹ More precisely, the issuance will be the responsibility of the CDM registry administrator working under the authority of the CDM EB. See "*Report of the Conference of the Parties on Its Seventh Session, Held at Marrakesh from 29 October to 10 November 2001*," (21 January 2002), FCCC/CP/2001/13/Add.2, p. 40.

wind farms in Egypt. The financial modeling shows that, given the conditions and costs that are likely to apply to a 60 MW wind farm at Zafarana, selling the emission reductions creditable to the project would improve the project's financial viability.

Two variables are used to illustrate the impact of CO₂ revenues on the project's financing. The first variable is emission reductions per annum. The second variable is the revenues per ton of CO₂ that could be realized.

6.5.1 Baselines

The tables below compare the business-as-usual (without CO₂ revenues) financial indicators with three CDM cases, each with a different baseline. The three CDM cases correspond to three of the seven baseline emission reduction scenarios developed in chapter 4. These three cases were selected for use in the modeling as they provide a low, middle, and a high figure for CO₂ emission reduction, and are thus illustrative for financial analysis purposes. The annual emission reductions figures used for the three cases are:

Case A: Historical/all plants = 147,513 tons of CO₂/annum

Case B: Economically attractive NG plant = 181,465 tons CO₂/annum

Case C: Last five year additions-all fuels (top 20%) = 159,322 tons CO₂/annum

It should be kept in mind that the values given in Table 12 and Table 13 reflect relative changes in financial performance resulting from various baseline and pricing scenarios. The values should not be taken as indicative of the returns that could be expected from wind energy projects in Egypt.

CO₂-Price

Two different prices for CO₂ are used in the modeling: US\$2/ton and US\$10/ton. These two prices are seen as spanning the bracket of prices, which this type of project (renewable energy in a developing country) could expect in the CO₂ offset market. The \$2 price can be taken as a conservative but realistic estimation based on the present market conditions. The \$10 price can be seen as an optimistic expectation, from the project partners' perspective, about future market development.

Table 12: Financial results with US\$2/t CO₂ CER price.

| Indicator | B-a-U | + CO₂/a | + CO₂/b | + CO₂/c |
|-----------------------------------|--------------|---------------------------|---------------------------|---------------------------|
| Economic internal rate of return* | 5.63% | 6.32% | 6.48% | 6.37% |
| Economic net present value* | \$2,954,117 | \$6,314,392 | \$7,120,329 | \$6,594,709 |
| Return on equity after taxes | 19.10% | 20.96% | 21.36% | 21.10% |

* Excludes financing costs, i.e., interest on loans.

Table 13: Financial results with US\$10/t CO₂ CER price.

| Indicator | B-a-U | + CO ₂ /a | + CO ₂ /b | + CO ₂ /c |
|-----------------------------------|-------------|----------------------|----------------------|----------------------|
| Economic internal rate of return* | 5.36% | 9.01% | 9.75% | 9.27% |
| Economic net present value* | \$2,954,117 | \$20,320,777 | \$24,350,463 | \$21,722,361 |
| Return on equity after taxes | 19.1% | 27.34% | 29.0% | 27.93% |

* Excludes financing costs, i.e., interest on loans.

6.6 Conclusions

6.6.1 Business as Usual Compared to the CDM

In all the different pricing and baseline cases considered it is financially beneficial for the project to pursue the CDM route. The project's return on equity is increased (for the best case baseline) by between 2.26% (CER at \$2) and 9.9% (CER at \$10). This conclusion bears out the prediction made in the "quick scan" assessment presented earlier in this section, namely that turning a conventional wind energy project of this size and scope into a CDM project would definitely be beneficial to the project's investors.

The CDM's impact on a project's finances depends both on the baseline and on the CER price. Developers should attempt to maximize both variables.

It is important to note that CER revenues alone would not be sufficient to make a non-viable project of this nature financially viable. But the CER revenues can turn a marginally viable project into a project with more attractive returns and raise the project in an investor's ranking of possible investments and thus increase the likelihood of investment being secured and the wind park being constructed.

The particular context of this project must be kept in mind. Other projects might have different costs, electricity tariffs, and baseline conditions, as well as different capacity factors, which may lead to less or more favorable results.

6.6.2 Implications of Different CO₂-Prices

Depending on the CO₂ price and the baseline scenario, the discounted net present value of the CERs can represent a value of between 5-30% of the project's capital cost. Even at the lower rate this is a significant amount and would influence the financial viability and architecture of the project.

A five-fold increase in the value of CERs (from US\$2 to US\$10) raises the project's return on equity by about 8%. This indicates that the project's finances are not very sensitive to changes in the CO₂ price, i.e., once the CO₂ financing has been secured then small changes in the actual value of the CERs are unlikely to influence the project's financial results significantly.

In sum, the CDM can have a positive impact on the likelihood of a project being implemented. It is therefore advisable and likely that projects of this type would be developed as CDM projects.

6.6.3 Implications of Different Baselines

The effect of the roughly 20% difference between the “best” (181,465 tCO₂/annum) and the “worst” (147,513 tCO₂/annum) baseline is an increase of the project’s return on equity by between 0.4% (US\$2) and 1.66% (US\$10), respectively. The project’s finances are thus not very sensitive to changes in the baseline either. When evaluating different baseline scenarios the project developer should therefore not simply try to pick the case that maximizes emission reductions, but should also take into account other aspects, such as ease of establishing and verifying the baseline and the certification costs, as they would vary depending on choice of baseline.

6.6.4 Risk Mitigation through CO₂ Revenues

Securing the income stream from selling the creditable emission reductions from the project would have a beneficial effect on the project’s financial structure. Not only do the CERs mean increased income to the project, but they also constitute an income stream separate from the sales of electricity. This diversification in income reduces the project’s overall financial risk and therefore the project’s cost of capital. Not only is the project’s income stream diversified but, since CERs would be valued and sold in an OECD currency (such as US Dollars or Euros), it is an income stream which is not subject to normal developing country currency risk. In comparison, the power generated from a CDM wind park would generally be sold in the local currency, which is subject to country and currency risk.

6.7. Summary

This chapter addressed the core issue of turning emission reductions into cash flow on a project and the impact of selling the emission reductions on project financial viability. The financial analysis was done through two spreadsheet-based models, which are specifically developed for this purpose. The models enable the financial analysis under different baseline scenarios for a 60 MW wind farm financed according to normal non-recourse (project finance) principles, both with and without the costs and benefits which would result from the sale of the emission reductions. The financial analysis does not assess the financial viability of wind energy in Egypt as such, but provides a tool to assess and evaluate the implications of different “carbon financing” scenarios on the project’s financing and illustrates the difference that the CER income makes to the project’s financing.

It is advisable to do a “quick scan” assessment of the impact of potential CER revenues on a project’s finances before embarking on the CDM process. The “quick scan” approach could produce results that are a fair approximation of what can be expected from a more comprehensive CDM analysis. It should be stressed that CO₂ revenues would not turn a financial “disaster” of a project into a “star”. What it can do, however, is to put a marginally viable project on a sounder financial basis. Depending on the CER price and baseline scenario, the discounted net present value of the CERs can represent a value of between 5% and 30% of the project’s capital cost.

The financial analysis examined the impact of CO₂ revenues for two different CO₂-prices (US\$2 and US\$10 per ton of CO₂) and for each price the implications of three different emission reduction baselines (best, worst, and average in terms of amount CO₂ mitigated) were determined.

In all the different pricing and baseline cases considered it is financially beneficial for the project to follow the CDM route. The project’s return on equity for the best case baseline is increased by

between 2.26% (CO₂ at \$2/tCO₂) and 9.9% (at \$10/tCO₂). This conclusion bears out the prediction made in the “quick scan” assessment presented earlier in this section: Turning a conventional wind energy project of this size and scope into a CDM project would definitely be beneficial to the project’s investors.

The implication of the difference of around 23% between the “best” and the “worst” baseline is to increase the project’s return on equity by between 0.4% (US\$2) and 1.66% (US\$10), respectively. The financial results are not particularly sensitive to changes in the CER price. The five-fold price increase from US\$2 to US\$10 raises the project’s return on equity by more than 8%. Considering the relatively low sensitivity to changes in the baseline it is therefore advisable when selecting a baseline to try not only to maximize the attributable emission reductions but also to take into account other factors such simplicity and transparency in establishing the baseline and the monitoring and verification procedures.

Based on this analysis it can be concluded that even if the effect of CO₂ revenues on the overall project’s return on investment is fairly limited for the low (\$2) CO₂ price, it could still raise the return on equity for the project’s investors by some 2.26%. This is a quite significant result for a conservative scenario and might be enough to make the difference between a project go-ahead or a project-stop.

In short it can be concluded that the CDM creates a suitable and advisable financing option to use in case of projects such as the wind park in Zafarana.

APPENDIX 1. FINANCIAL SPREADSHEET MODEL

The sections below describe the MS EXCEL based financial analysis model used in the report.

ASSUMPTION AND INPUTS

The following assumptions are listed on the “Assumptions” sheet in the model.

| ASSUMPTION | DESCRIPTION |
|------------------------------|---|
| Wind Farm Performance | |
| Installed capacity | Rated capacity of the wind turbines installed at the wind farm |
| No of WTG | Number of wind turbine generator units |
| Full Load Hours | Number of hours per year that the turbines will generate power at their rated capacity |
| Capacity factor | The percentage of full load hours per year |
| Nominal power production | Power (kWh) produced by the wind park per year based on capacity factor |
| Wind farm reduction factor | Reduction in nominal power production due to diverse losses in the actual wind farm. |
| Projected Power Production | Actual expected power production taking into account the wind farm reduction factor |
| General | |
| Economic Lifetime | Number of years of expected operation |
| Inflation | Average inflation rate over project lifetime (used for comparison purposes and not as an input to modeling) |
| Discount Rate | Rate at which the future value streams are reduced compared to value at start-up year |
| Electricity escalation | Rate at which the electricity tariff increases over time (0% in this case) |
| Electricity tariff | Price at which electricity produced at the wind farm is sold (\$/kWh) |
| Other Electricity value | Additional value or subsidy provided to the wind farm in order to make it commercially viable. This can include factors such as true avoided cost of generation, capacity payments, voltage relief, deferred investment in transmission upgrades. |
| Total Electricity tariff | This value also covers for inaccuracies in all the other values used in the modeling The sum of the electricity tariff and other electricity value |
| Depreciation period | Number of years over which the capital devaluation of the wind farm is used as a tax deductible expense |
| Flat Rate Depreciation | Annual rate of depreciation |
| Flat Tax rate | Tax rate to which the wind farm’s profits will be subject |

Capital Costs

| | |
|------------------------------------|---|
| Turbines | Cost per turbine |
| Wind Farm EPC | Cost of the Wind farms to the point of being installed on site |
| Civil works | Cost of ancillary civil works such a roads, foundations etc |
| Installation | Cost of installing the turbines |
| Electrical works | Cost of connecting the wind farm to the electricity network |
| Development Costs | Cost of planning and managing the project up to financial closure |
| Total Capital costs | |
| Capital Subsidy (% of total costs) | Subsidy provided if relevant |
| Total Capital Investment | Total capital cost after subsidies |

Operational costs

| | |
|--------------------------------------|---|
| O&M costs per year | Operation and Maintenance costs |
| O&M costs (year 1) | |
| O&M escalation (year 1-10) | |
| O&M costs (year 11 - 20) | |
| O&M escalation (year 11-20) | |
| Other operating costs incl insurance | |
| Human resources | Labour cost per annum |
| CO2 M&V cost | Cost of monitoring, verifying and certifying emission reductions per certification period |
| Refurbishment year | Cost of refurbishing specific components of the wind farm during its lifetime |
| Refurbishment cost | |

Finance

| | |
|-------------------------------|--|
| Equity | |
| % of Total Capital Investment | % of capital cost that will be provided by the investors |
| Value | Value of the capital investment |
| Commercial loan | |
| Commercial Interest rate | Rate at which debt is rated |
| Period | Period over which debt will be repaid |
| % of Total Capital Investment | % of capital cost covered by debt (100% - equity) |
| Value | Value of Debt |

Emission reductions

| | |
|--------------------------|---|
| CO2 equivalent mitigated | Annual reductions in greenhouse gas emissions in equivalent tons of CO ₂ |
|--------------------------|---|

| | |
|-------------------|--|
| CO2 annual income | Income per annum from sales of certified emission reductions |
| CO2 setup cost | Cost of registering the project as an CDM project, cost of emission baseline development |

FINANCIAL ANALYSIS

The different financial analysis sheets (Fin BAU; FIN CO2 a; FinCO2 b; FIN CO2 C) use a cash flow based analysis using annual figures to calculate a number of indicators of financial performance (Internal rate of return (IRR), Return on Equity, Debt Service Cover Ratio, Min Debt Service Cover Ratio, Interest Cover Ratio, Minimum Interest Cover Ratio) using standard financial functions.

Two sets of financial analysis spreadsheets are provided which make the financial analysis under various baseline scenarios for two different CO2 prices (US\$2 and US\$10)

A number of different scenarios are analyzed, each on a separate sheet. The Fin BAU (business as Usual) sheet examines the project's finances in the absence of any CO₂ costs or revenues. The other "Fin" sheets each determines the impact of different CO₂ baselines.

The inputs to the financial analyses sheets are listed on the Assumptions sheet. Any changes on the assumption sheet will automatically change the inputs on the financial analysis sheets

REPORTS

The reports sheets contain the results of each of the cash flow analysis sheets for easy comparison.

APPENDIX 2. REVENUES FROM WIND AND ELECTRICITY MARKETS

Introduction

This Appendix presents a simple Excel-based spreadsheet model. The model summarizes the assumptions and results of the economic assessment of the Zafarana wind park project. Moreover, it allows the user to change these assumptions.

So far, most economic assessments of wind power have been based on estimates of electricity generated from wind turbines on an annual basis, which is paid by a flat, subsidized rate. An important feature of the ongoing process of liberalization of electricity markets in many countries is that electricity prices may vary significantly – often on an hourly basis – with demand.

The model is a tool to study the impact of the choice of baseline and price profile for electricity. It may illustrate different market situations. It also illustrates the impact of emission reductions benefits and the choice of discount rate.

CDM Baselines for the Zafarana Project

There are basically two options for calculation of the baseline of a CDM project; project-specific baselines and standardized baselines. The project-specific baseline for wind power would require information on the type of thermal electricity that is substituted by wind in the different load intervals, and on the diurnal and seasonal profile of wind generation, whereas the standardized baseline only require information on the annual generation by wind power.

Figure 11 shows the data from Table 5 in chapter 5 in the form of a load duration curve for the thermal electricity generation in Egypt and the wind power in each load interval that may replace the least efficient part of the thermal generation. It is assumed that hydropower, which covers about one-fifth of the total demand, would not to be affected by the introduction of wind energy because the demand for thermal power is calculated on the basis of an optimization of hydro power – mainly from the Aswan Dam – which takes into account constraints on hydro generation from irrigation and peak electricity demand in the late afternoon. Figure 11 illustrates that wind power would be able to supply a significant share of the peak thermal demand.

Figure 11: Integration of 60 MW and 600 MW wind power into the Egyptian power system in 1999. Substitution of thermal power production and CO₂ emissions.

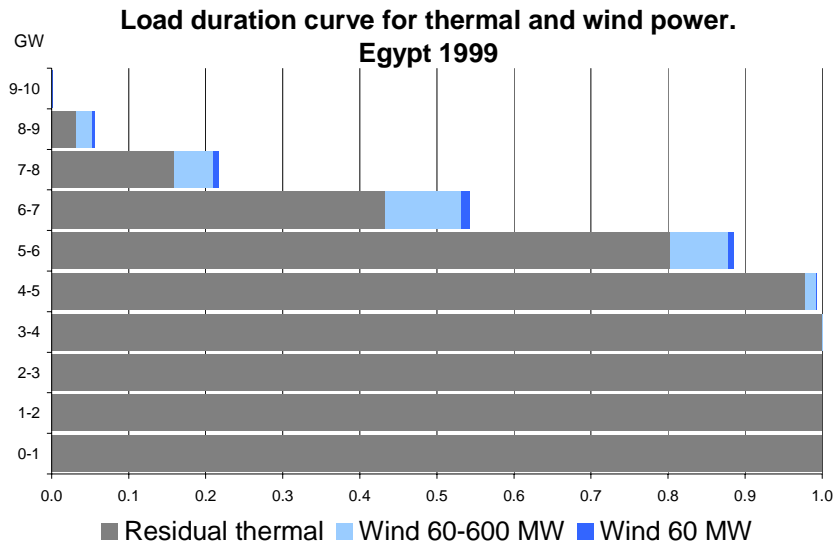
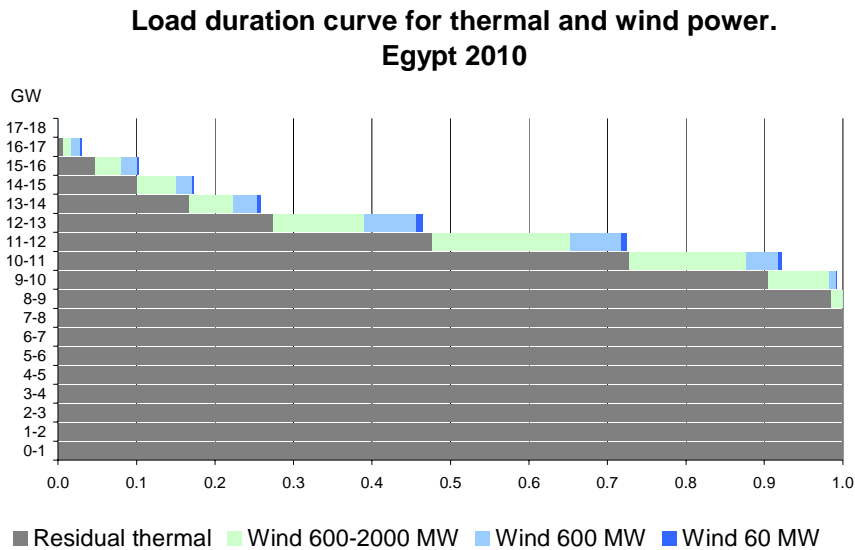


Figure 12 illustrates the results of the dynamic baseline study for 2010, cf. Table 10 in chapter 5. Peak demand has increased significantly and more thermal capacity has become available. In addition to the 60 MW and 600 MW wind farms, calculations were also made for a much larger wind capacity of 2,000 MW.

Figure 12: Integration of 60, 600 and 2000 MW wind power into the Egyptian power system in 2010. Substitution of thermal power production and CO₂ emissions.



Model Features

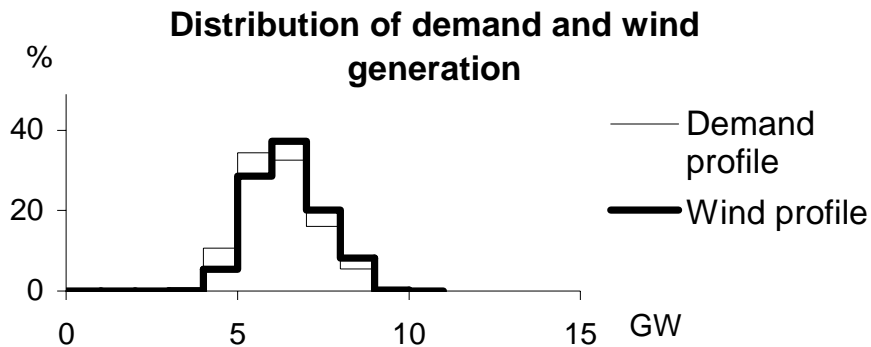
Figures 13-16 present some of the assumptions and results of the spreadsheet model. The assumptions are either entered as numbers by the user or selected from a small database using drop-down menus. Figure 17 gives the presentation sheet of the model containing both the main results and an overview of the assumptions. The case described in these figures is a 600 MW wind farm at Zafarana in the Egyptian electricity system by 1999 as analyzed in chapter 5.

Figures 13-16 highlight the four graphs in Figure 17. The horizontal axis is identical in the graphs, representing the hourly demand for electricity from sources other than hydro power.

Figure 13 compares the wind profile with the profile of the marginal thermal demand that may be replaced by wind energy. The figure illustrates that a relatively large share of the wind power may replace high and peak load thermal power. The demand profile is calculated as the difference between the demand in a load interval and the next (i.e., the difference in the length of the horizontal bars in Figure 11).

In economic dispatch the generation units are scheduled in merit order. The most efficient units would supply base load, while the less efficient units would be used for peak load when needed. In Egypt base load (up to 4 GW) would be supplied by units with thermal efficiency between 39% and 42 %, high load (4-7 GW) would be supplied by units with efficiencies between 33% and 38%, and peak load by units with efficiencies below 25%. Most thermal units are fuelled by natural gas. As Figure 13 illustrates, the profile of wind power in Zafarana is favorable in the sense that its contribution to high and peak load is relatively large.

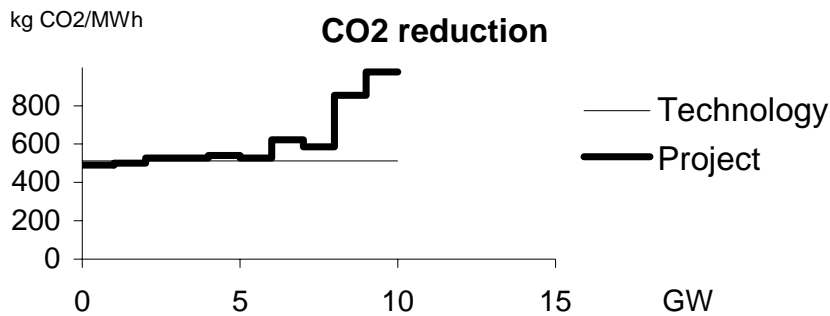
Figure 13. Distribution of demand and wind generation.



Unlike a static, standardized baseline, the project-specific baseline is able to assign this type of advantage (or disadvantage) to a CDM project. The standardized baseline is most easily calculated by using a reference technology, e.g., a gas turbine in the mid-merit range.

Figure 14 compares the Zafarana project's CO₂ reductions with two types of baselines. Assuming that wind would always replace the least efficient units, the project-specific baseline reflects the efficiencies of the marginal generating units in each load interval. In this example the static technology-specific baseline is a gas turbine with 40% efficiency.

Figure 14. CO₂ substitution by wind turbines per MWh wind generated electricity assuming reference technology or project specific baselines.



The project specific baseline follows from the project describing the wind profile in Figure 13, while the reference technology baseline is chosen from the drop-down menu to the right of the figure on the presentation sheet in the Excel workbook. The amount of CO₂ reductions per kW installed wind capacity per year, which is calculated by the spreadsheet model (see Figure 17 below), is strongly dependent upon the choice of reference technology:

- Project specific baseline 2577 kg CO₂/kW wind capacity per year;
- Gas turbine 35 % efficiency 2507 kg CO₂/kW wind capacity per year;
- Gas turbine 40 % efficiency 2193 kg CO₂/kW wind capacity per year;
- Gas CCGT 50 % efficiency 1755 kg CO₂/kW wind capacity per year;
- Future CCGT 55 % efficiency 1595 kg CO₂/kW wind capacity per year; and
- Future coal 50 % efficiency 2924 kg CO₂ per kW wind capacity per year.

Perhaps it would be expected that the project-specific curve in Figure 14 would be monotonically increasing. But this is not the case and the curve might illustrate a lack of efficiency in the economic dispatch. However, in more detailed economic dispatch low start-and-stop costs may outweigh the higher efficiency of thermal units that are used for load-following, or the variations in electricity generation by wind turbines.

In Figure 15 two examples of price assumptions for base case technology are compared. In both cases an average electricity tariff of \$28.90/MWh (or \$0.0289/kWh) is assumed for sale of generation from the wind park. The variation in the technology substitution price reflects the different efficiencies of the thermal units that are specified in the project specific baseline and the demand profile, while the flat rate at \$28.90/MWh is assumed as sales price for electricity from the wind farm project.

Figure 15. Electricity price for baseline and electricity sales from wind farm.

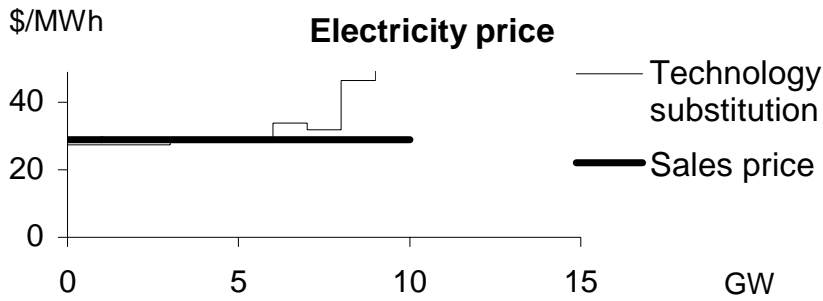
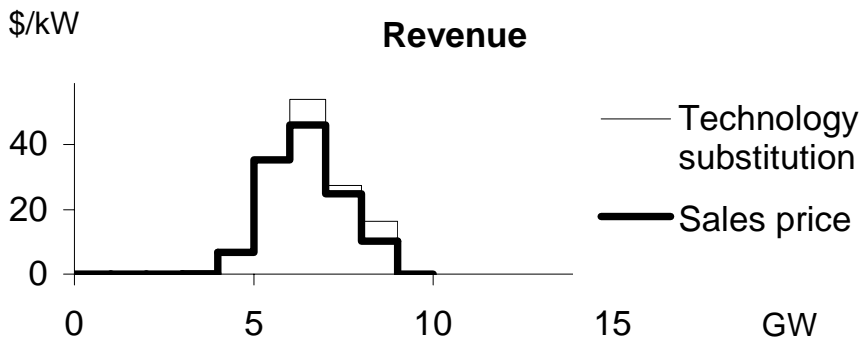


Figure 16 compares the revenue of electricity sales using the fixed sales price at 28.90 US\$/MWh with a baseline price that is adjusted for variations in the efficiencies of the technologies that are substituted by the wind farm project, but with the same average price for all electricity. In this case there would be a higher average value of the wind electricity, namely 32.80 US\$/MWh. This figure is found in the first column, labeled “Technology” in the bottom part of the table on the presentation sheet.

Figure 16. Revenue from sale of wind power.



Presentation Sheet

Figure 17 shows the presentation sheet for the spreadsheet. The presentation sheet allows the selection of some assumptions by the drop-down menus or entered as numbers, while the more detailed assumptions behind the drop-down menus, e.g. load profiles, are found in other sheets.

The assumptions, which may be changed on the reporting sheet, are:

- Investment cost for the wind park per kW installed,
- Annual operating and maintenance costs per kW installed,
- Discount rate and economic lifetime,
- Custom prices for electricity in € or \$ per MWh, and
- Emission reduction benefits in € or \$ per ton CO₂ reduced.

“Custom” prices for technology substitution or sales prices for the electricity from the wind farm are active only when the “Custom” data are selected in the drop-down menus above the cells containing the custom price input.

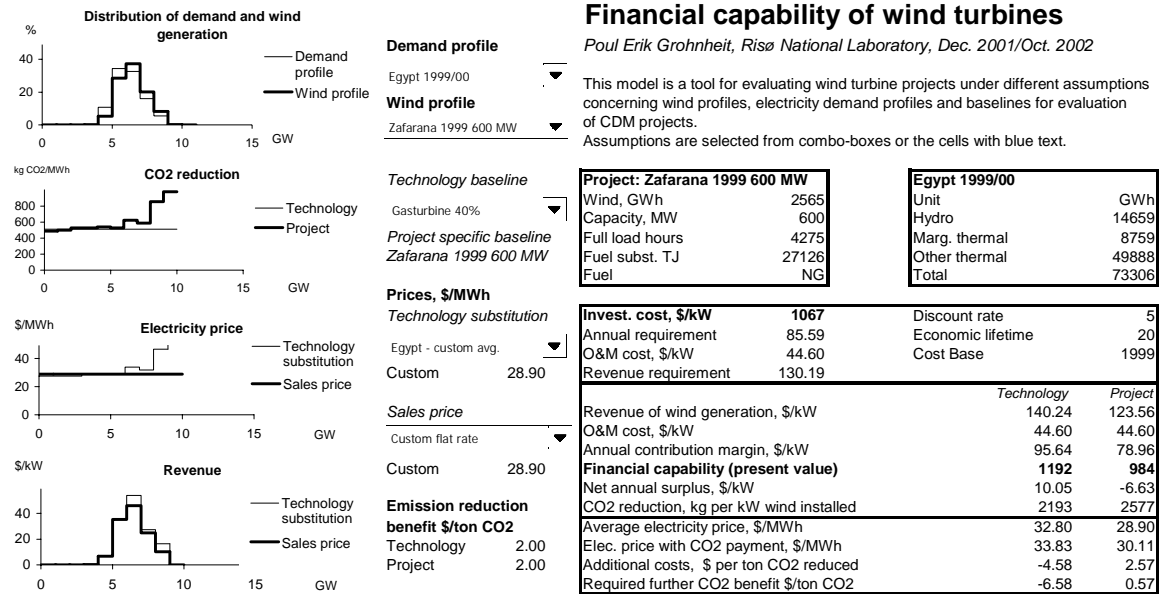
These prices are key assumptions for the financial capability of the wind farm project. With the assumptions summarized in Figure 17 the annual revenue of the wind farm project is calculated to \$ 123.56 per kW installed wind capacity. Assuming operation and maintenance (O&M) cost \$ 44.60 per kW, the annual contribution margin to recover capital cost is \$ 78.96 per kW. The present value of this annual payment over 20 year with a 5 % discount rate is \$ 984 per kW. This is the financial capability of the wind farm, which should be compared to the investment cost of the wind farm. Figure 17 shows this cost is assumed to be \$ 1,067 per kW installed.

The more detailed datasets are selected by using the drop-down menus:

- Demand profile for Egypt 1999-2000 and 2010;
- Wind profiles for 60, 600 and 2,000 MW;
- Standardized baseline technology;
- Price profile for technology substitution; and
- Sales price profile for wind energy.

The data to be selected by the drop-down menus are found in the sheet “Data”. All these data are profiles, which are dependent on the load intervals in the selected country or region.

Figure 17. Spreadsheet model for wind farm in a regional electricity system (600 MW wind in 1999).



With the data for the wind profile at Zafarana and the electricity demand profile and existing technologies in Egypt in 1999 the financial capability of the substituted electricity generation is higher, namely \$ 1,192 per kW. This also exceeds the assumed investment cost.

CO₂ payment at \$ 2.00 per ton CO₂ would bridge part of the gap between the financial capability of the wind farm project and the investment cost. However, in the case illustrated in Figure 17, further \$ 0.57 per ton CO₂ would be required.

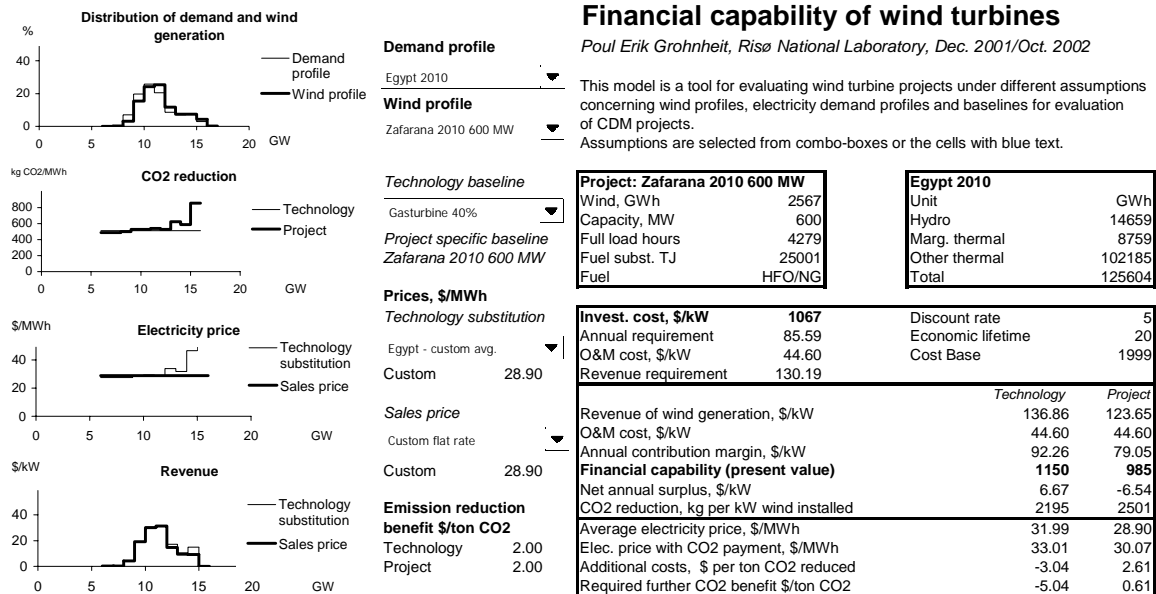
A key assumption is the discount rate. The 5 % discount rate used in Figure 17 is far too low for most financial markets. Changing the discount rate to 10 % would reduce the financial capability of the project to \$ 672 per kW and the required further CO₂ benefit would be \$ 15.98 per ton CO₂.

Running the Model

Figures 18-19 show examples of the use of the model to calculate the consequences of different assumptions for demand profile, wind farm projects and the electricity market.

In Figure 18 the wind farm project is unchanged, but the baseline describes the expected demand profile and thermal generating capacities in Egypt by the year 2010. With no other changes in the assumptions the difference in the financial capability of the wind farm project between 1999 and 2010 is negligible. Nor would a larger wind farm project at 2,000 MW make any significant change to the financial capability (\$ 981 per installed kW compared to \$ 985 for the 600 MW wind farm).

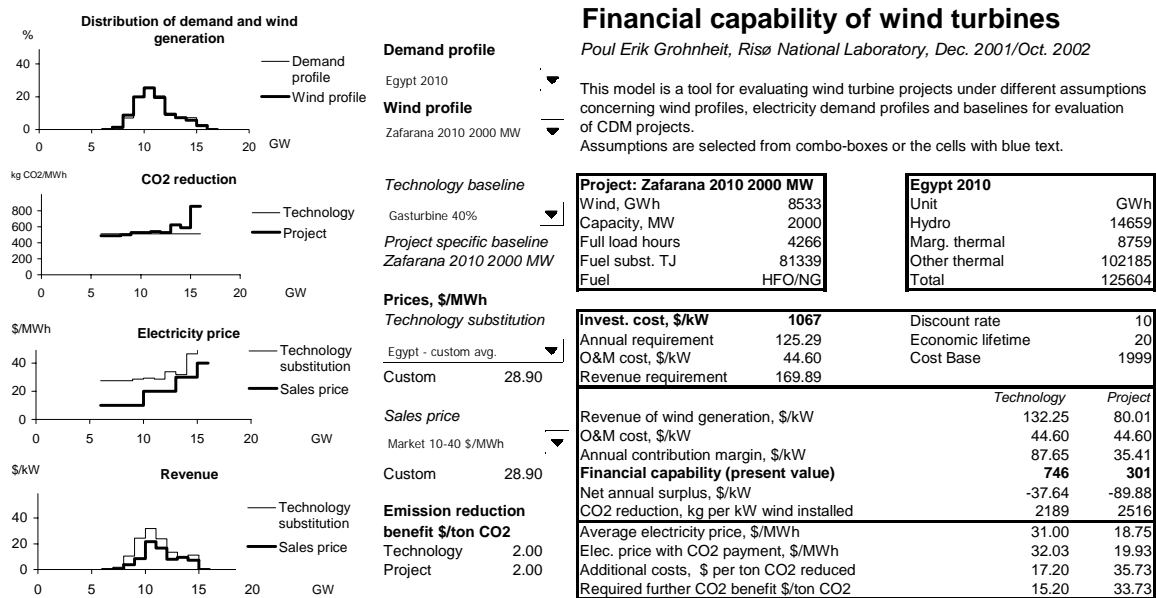
Figure 18. Spreadsheet model for wind farm in a regional electricity system (600 MW wind in 2010).



If the drop-down menu “Sales price” is set at “Substitution rate” and the custom price is the average price for “Technology substitution”, the results in the two columns “Technology” and “Project” become identical. It follows from Figure 18 that the financial capability of the wind farm project under these assumptions is well above the investment cost for the wind turbines. This would often be a requirement for the justification of any subsidy or emission reduction benefit.

Figure 19 illustrates the choice of time and load dependent prices for sale of electricity from wind turbines. In a liberalized market these price differences can be quite significant. The prices shown vary from 10 € or \$ per MWh at base load to 40 € or \$ per MWh at peak load. Keeping the discount rate at 5 %, the financial capability would be \$ 441 per kW installed wind capacity. However, a discount rate at 10 % or higher is more consistent with a liberalized market. This would reduce the financial capability to \$ 301 per kW as shown in Figure 19, far below the investment cost.

Figure 19. Spreadsheet model for wind farm in a regional electricity system. (2,000 MW wind in 2010) with variation of electricity sales prices and 10% discount rate.



The options in the spreadsheet can easily be extended and the model can be used for a systematic study of all relevant combinations of options.

7. SUSTAINABILITY ASSESSMENT OF ZAFARANA

7.1 Introduction

Article 12 of the Kyoto Protocol defines the CDM as a mechanism to enhance the sustainable development of the host country. To ensure that CDM projects are compatible with sustainable development objectives, policymakers in developing countries need information about the alternative choices involved and how CDM projects affect clear and recognizable social, economic and environmental issues. Hence, it is useful to develop a set of indicators that could provide the basis for evaluating project's performance in achieving sustainability goals and targets.

This chapter deals with the sustainability assessment of the Zafarana project. The analysis is organized as follows:

- a) The first task of the assessment is the definition of the dimensions or properties to be sustained. This topic is addressed in section 7.1.
- b) Making the concept of sustainability operational requires the identification of a set of specific indicators that can provide precise information about the satisfaction of sustainability dimensions. This is done in section 7.2.
- c) Section 7.3 discusses the project's impact on different dimensions of sustainability. The set of indicators provides criteria as to whether properties of sustainability are met.
- d) In section 7.4, the overall assessment of the project sustainability is carried out. A qualitative multicriteria evaluation is applied to measure the degree of sustainability and to test the sensibility of the analysis.
- e) A summary of the findings and conclusions are presented in section 7.5.

7.2 The Approach

The past few years have witnessed a rapidly increasing interest in the construction of sustainable development indicators to assess the significance of sustainability concerns in economic analysis and policy. A number of analytical frameworks (Hardy and Barg, 1997) have been suggested to define, to develop and to communicate indicators of sustainability. Different disciplines have their own conceptual framework that translates into different indicators with different normative basis. The main differences among frameworks are: (i) the ways and means by which they identify measurable dimensions, and select and group the issues to be measured; (ii) the concepts by which they justify the identification and selection procedure. Economists stress the goal of maximizing the net welfare of economic activities, while at the same time maintaining or increasing the stock of economic and ecological assets over time. The social approach tends to highlight issues related to inequality and poverty reduction, while environmentalists focus on the question of natural resource management and ecosystems' resilience (IPCC, 2001).

Apart from differences in perspectives and conceptual backgrounds applied, the identification of indicators for sustainable development needs more clarity and consensus about the definition of what an indicator is and what an indicator is trying to measure. Indicators for sustainability generally tend to cover every aspect of pollution control, nature conservation, resource depletion, social welfare, education, employment, waste management, etc.—in short, a compendium of all the components of traditional development goals and conventional policy debate. Hence, factors that distinguish sustainable development from traditional development tend to be submerged under a sea of age-old problems that are made no more readily soluble by bearing the name of sustainable

development (IPCC, 2001). Additionally, most indicators are focused on those segments of sustainability that can be quantified and expressed in monetary or physical units. Crucial aspects of sustainable development tend to be ignored either because quantitative information is not available or because of the non-quantifiable nature of a particular aspect (George, 1999).

In recent years important steps have been undertaken to capture the multiple dimensions of sustainable development and incorporate them into an operational framework (Bossel, 1999; Meadows, 1998). Among them, the System Orientor Theory (Bossel, 1998, 1999) (the approach applied in the present analysis) has been introduced to system analysis theory in an effort to transcend current disciplinary and conceptual boundaries to analyzing and elucidating criteria of sustainable development and to identifying indicators so that progress toward sustainability can be measured.

The System Orientors approach addresses sustainability as a basic property of complex systems. As a systemic property, sustainability is a rather simple and straightforward idea; a system is sustainable or viable if it is able to persist, grow, and develop within its normal environment. The process of growth and development requires any system to pay attention to a number of properties or “orientors” that constitute the basic conditions or dimensions of its viability. The following dimensions are important (Bossel, 1999):

- (i) *Existence*: The system must be compatible with and able to exist in its normal environmental state.
- (ii) *Effectiveness*: The system should on balance be effective in its effort to secure scarce resources.
- (iii) *Freedom of action*: The system must have the ability to cope in various ways with the challenges posed by its environmental variety.
- (iv) *Adaptability*: The system must be able to generate appropriate responses to challenges posed by its environmental change.
- (v) *Coexistence*: The system must be able to modify its behaviour to account for behaviour and interests of other systems (actors) in its environment.

In order to operationalize this framework, it is necessary to identify a set of indicators that can provide unambiguous information about how the Zafarana project performs on each of the above-mentioned sustainability dimensions. It is clear that several indicators are possible as representation of each dimension and, furthermore, that their selection is influenced by a dose of subjective criteria. This situation is inevitable because the choice of indicators arises from values (Meadows, 1998) and is determined by knowledge about and perception of the problem in question (Bossel, 1999).

7.3 Indicators of Sustainability

The Zafarana project is viewed here as a process of technological innovation that introduces a new component or subsystem into the Egyptian energy system. This process creates new prospects for achievement of developmental goals and aspirations. Indeed, the introduction of a novel technology opens up new niches and opportunities for new interactions among economic agents and technologies, opportunities that are exploited by the progressive modifications of the agents. The process of technological innovation fosters the co-evolution of a web of linked economic compartments and nodes that results in energy and in general economic systems more diverse and efficient in generating future outputs. In the case of the Zafarana project, the implementation of the wind farm technology would lead to a more diversified energy supply

system that is less dependent on exhaustible energy sources and more resilient to external shocks. At the same time, a significant deployment of wind turbines could foster the development of a web of mutually reinforcing economic activities.

But, as any technological change, the introduction of new energy technologies, apart from trivial cases, represents a (positive or negative) destabilizing factor within the energy system. The implementation of the technology requires alterations in organizational and technological webs if advantage is to be taken of this new opportunity. For example, the introduction of wind farm technology into the national grid system involves modifications of existing planning practices and operation procedures. The fluctuating power output from wind turbines (due to the variability of the wind speed) requires, among other things, altered dispatching routines, adaptation of analytical tools for optimal power evacuation, and new technical solutions for the prevalent grid integration problems. Moreover, operation and maintenance involves the existence of a service-supplier network to ensure standards levels of efficiency. This means that the existing technical and managerial structures would be altered and the contextual environment must provide the necessary conditions for the viability of the technology.

The above remarks lead to the observation that the question related to the viability of the Zafarana project needs a set of indicators able to deal with two interrelated perspectives. On the one hand, the contribution of the project to a more sustainable or viable development of energy systems and the economic system in general and, on the other hand, the sustainability or viability of the project within the technological and economic context within which it would be implemented. Different sets of indicators are suggested here for analyzing these two issues. They are summarized in Table 14.

Concerning the question of the viability of the project, the scope of the indicators is as follows:

- a) *Suitability and urgency*: the extent to which the project responds to national objectives and energy sector priorities.
- b) *Cost effectiveness*: the cost per kWh of electricity generated by the project.
- c) *Risk of obsolescence*: This indicator includes (i) the economic obsolescence of the investment due to rapid performance improvements and significant cost reductions of the wind technology, and (ii) technical obsolescence due to the lack of technical support.
- d) *Flexibility*: the capability of the wind technology to be adapted to the operational characteristics of the power supply system.
- e) *Technological capability*: the existence of an appropriated contextual environment (human and organizational resources, institutions, service-supplier networks) to support the technology throughout its lifetime.

Table 14: Indicators of the sustainability of the Zafarana project.

| Sustainability dimension (orientor) | Indicators of sustainability | |
|-------------------------------------|--|--|
| | Viability of the Project within the Egyptian technological context | Contribution of the project to the sustainability of the economic and energy systems |
| Existence | Suitability and urgency | Suitability and urgency |
| Effectiveness | Cost effectiveness (energy) | Efficacy on GHG reductions |
| Freedom of action | Risk of obsolescence | Resilience |
| Adaptability | Flexibility | Technological diversification |
| Coexistence | Technological capability | Environmental impacts |

The issue related to the contribution of the Zafarana project to the sustainability of the overall power system is addressed throughout the following indicators:

- a) *Suitability and urgency*: as explained above.
- b) *Effectiveness of GHG reductions*: the potential for and cost-effectiveness of GHG reductions.
- c) *Resilience*: the contribution of the project to expand the resource-base of the energy system as well as to increase its resilience to eventual external shocks.
- d) *Technological diversification*: the contribution of the technology to enhance the diversity of the national techno-economic system.
- e) *Environmental impacts*: the extent to which the project affects the environment.

The next two sections present a summary evaluation of the expected project performance in relation to the indicators.

7.4 Performance of the Zafarana Project

7.4.1 Viability of the Zafarana project

Suitability and Urgency

Above all, the suitability and urgency of a new technology is determined by overall national sectoral priorities. The introduction of wind farms is in line with the power sector strategic goals established by the Egypt Energy Authority (Gelil et al., 2001). National energy development objectives, such as “optimizing indigenous energy resources”, “maximizing the utilization of non-combustible resource”, and “implementing efficient and environmentally sound technologies,” necessarily entail the deployment of large-scale wind power generation, particularly in view of the huge wind resource potential along the Gulf of Suez zone (NREA-RNL, 2001). Therefore, it is not surprising that a renewable energy strategy has been incorporated into national energy planning as an integral element of the Egyptian long-term energy development. A target of 5% of

the primary energy consumption supplied by renewable energies by 2005, which involves the installation of 600 MW of wind power capacity, has been envisaged by NREA. In the longer term NREA foresees to increase the wind power generation capacity to 2,000 MW.

In addition to strict energy-related considerations, the deployment of wind farms responds to broader development priorities. According to the SNAP study on GHG Mitigation and Adaptation Technology Assessment (see Table 15), wind power has received the highest score among several technologies analysed in the study. A set of social and economic criteria including employment creation, implementation and management conditions, and revenue distribution were used to ranking the potential GHG mitigation options.

Table 15: Evaluation of social and cultural impacts of GHG mitigation technologies. (SNAP, 1997).

| Technology | Score |
|--|-------|
| Wind power generation | 98 |
| Combustion control | 85 |
| Efficient lighting systems | 79 |
| Combined heat and power production | 77 |
| Waste heat recovery | 61 |
| Steam condensate recovery | 53 |
| Substitution of oil by natural gas in industries | 48 |

It is clear from the above remarks that the Zafarana project responds to the objectives and priorities of the Egyptian development strategies. The project is not just a suitable alternative towards the enhancement of the energy system robustness but also a technological choice with a non-negligible potential for attaining broad economic and social goals.

Effectiveness

To be sustainable, one of the basic requirements for the wind energy project is its ability to compete against conventional electricity generation technologies. In fact, within a business context electricity is a homogeneous commodity good and wind turbines are valued in the market place almost exclusively as a producer of electricity and, as long as markets for “green power” and “greenhouse gas emission-free power” do not exist, can only compete on price. Thus, unlike new technologies in other industries, wind turbines cannot command a higher price based on quality features and still capture a market share.

The standard cost/benefit assessment of the Zafarana project (chapter 6) shows that the cost per kWh, assessed under “market conditions”, is higher than the purchase prices established by the Egyptian Electricity Authority (EEA). This means that the project is not profitable and the prevailing conditions are not sufficient to encourage private investments in wind energy. A number of scenarios for the project profitability could be envisaged in the short-term.

First, the costs of manufacturing wind turbines are expected to continue their declining tendency in the future. But, as it is discussed in the next section, no substantial reductions in costs are

expected in the near future. Therefore, it is unlikely that the project profitability would be affected by short-term trends of prices in the international market of this technology.

The second factor is related to the power purchase prices practiced by the EEA. Electricity tariffs in Egypt are heavily subsidized (Gelil et al., 2001). The programme oriented to escalate the energy prices gradually to their economic levels was abandoned a few years ago due to social and political reasons. At present, the Government has established a Business Plan to introduce market mechanisms into the electricity sector management. One of the objectives of the plan is to give the private sector opportunities to operate on a competitive economic basis. This new policy would necessarily entail the gradual elimination of subsidies and certainly a steady increase of electricity tariffs.

Even in the unlikely case of unchanged tariffs, a policy of “subsidies” to the wind energy could be in the interest of the government. Losses in fiscal revenues due to a policy of incentives to wind energy development (tax credits, temporal elimination of import duties or higher electricity purchase prices) could more than be compensated by the resulting decrease of subsidies to power sector. Moreover, the Government could also benefit from export of the avoided consumption of oil or natural gas in thermal generation.

Lastly, the ancillary benefits from the carbon emissions avoided by the project play a non-trivial role from a profitability point of view. The financial analysis in chapter 6 shows that the revenues from sales of carbon offsets enhance the financial viability of the Zafarana project. Yet, at present, the market share of CDM activities relative to the potentially tradable amount of GHG reductions through the Kyoto mechanisms is highly uncertain. Preliminary estimates vary between 300 MtC and 700 MtC by the year 2010 (Baumert et al., 2000). Given these uncertainties, it is difficult to estimate the market price of CERs.

In conclusion, the financial viability of the Zafarana project hinges on (i) the strategy adopted by the Egyptian government on energy subsidies, (ii) the incentives to encourage production of electricity by wind turbines under the electricity sector reform, and (iii) the direction and magnitude of the carbon market under the Kyoto mechanisms. Ongoing tendencies point to a favorable environment for the economic sustainability of the project.

Risk of Obsolescence

It has been recognized that some minimal insulation from the risk of obsolescence is a paramount criterion in technology transfer, particularly when its implementation involves substantial investments. The explanation for this is straightforward. First, the transferred technology must be capable of being supported throughout its useful life. Second, committed investments must be protected against major breakthroughs in the efficiency and costs of the technology. Concerning the wind turbines the following remarks are worth to note.

After some radical innovations (AC motor control technology, newer fiber-glass construction techniques, aerodynamic models) the development of the wind energy technology has experienced no major innovations in the last years (Loiter et al., 1999). While individual components have been redesigned to address the problems of increasing the size of the turbines and improving the overall performance, the overall configuration of the turbine have remained constant. According to Loiter et al. (1999) this method has allowed the manufacturers to introduce a “new” model almost every year or two, or perhaps slightly larger but substantially similar to the previous model. Thus, in contrast to the photovoltaic technology—whose development is expected to undergo a series of discontinuities until a dominant design in a

mass-market may materialize—the wind power technology has entered into a standardization stage. Performance improvements and cost reductions are expected in the future but these incremental changes would take place around the basic innovation standards already in the market (Grubler et al., 1999).

Concurrently with technological developments, in the last years the wind electricity technology has undergone a transition from the innovation and niche market commercialization to the early stage of pervasive diffusion (Grubler et al., 1999). In its recent paper *White Paper on a strategy for the development of renewable energy*, the EU-Commission has launched a goal of covering 12% of energy consumption by 2010 with renewable energy technologies. In the implementation of this target, the development of wind power is expected to play an important role. The installed capacity of wind power is proposed to grow from 6.5 GW in 1998 to 40 GW by 2010.

The costs of the technology have come down dramatically over the last decade of commercial wind power to 20% of the 1980-level (Loiter, et al., 1999). A significant portion of the improvements occurred during the rapid increase in installed capacity in the mid-1980s. As a result of gained experience and cumulative output, a reduction in costs is still expected along the technology learning process. However, the potential for cost reductions becomes increasingly exhausted as the wind technology matures. Therefore, the impressive breakthroughs on costs and efficiency achieved in the past are unlike to happen in the future and the process seems to indicate that the slope of the learning curve has entered into a stable phase (Grubler, et al., 1999).

These three measures of a technology's stage of development—performance, costs, and market shares—indicate that the wind power technology has overcome the pre-competitive phase of demonstrative actions in limited niche markets to become a competitive and profitable technology. Wind technology is already a well-established industry with relatively long periods of obsolescence that guarantee its technological continuity and reduces significant changes in the cost/performance ratio. In conclusion, the choice of the wind farm technology does not entail major risks of obsolescence.

Flexibility

The Zafarana wind farm project is designed to for integration into the electricity network. It is known that the integration of wind energy into the grid poses a number of technical problems. Wind energy generation has a fluctuating power output, due to the variability of the wind speed. Such power fluctuations may affect both the grid operation as well as the quality of the power in the grid. Moreover, the evaluation of the impact of wind turbines on the power quality is a complex problem, due to the unique design of each distribution network. A number of experiences with wind energy technology in developing countries, although impressive in terms of capacity additions (the case of India, for example), have shown capacity utilization factor much below initial expectations due in part to technical integration problems into the electricity network (Rajsekhar et al., 1999).

Simulation analyses undertaken as part of the present feasibility study show that sufficiently good capacity utilization factors are possible under both the existing hydro thermal power generation capacity and the electricity demand profiles in Egypt. The relatively flat configuration of the terrain with no significant slopes and low wind climate gradients reduce the presence of turbulence effects affecting the efficiency of the turbines and the system operation (NREA-RNL, 2001). Moreover, at the present, with the increasing sophistication and reliability of tools and models, there is a great potential for reducing the cost of generation and increasing accuracy in predicting energy output of wind power plants. Egyptian experts are familiar with the usage of

these tools and the experience gained from demonstration projects has shown their capability to adapt the tools and models to the local operating conditions. Therefore, the integration of wind power into the national grid does not pose major technical problems.

Neither does power evacuation represent an operational constraint. A 220/22 kV substation equipped with two 75 MW transformers at Zafarana is already established together with a 220 kV transmission line for connection to the nearest S/ST in the national grid. Furthermore, it is planned to replace the transformer with two 125 kV transformers. These power evacuation facilities ensure a full exploitation of the wind-generated energy.

Technological Capability

Technological change is a process that takes place in a specific social, economic and technological context. The knowledge about how to perform individual processes embodied in the technology and how to combine them in an efficient process cannot easily be transferred since it depends on the contextual circumstances. At the same time, these circumstances require some alterations in order to take advantage of the opportunities offered by the technology. This means that the viability of a new technology depends heavily on the existence of an articulated web of functions to support the technology and able to assimilate the changes it brings about. In general, such a web should: (i) undergo changes in the whole spectrum of elements and processes related to the technology in question; (ii) experience continuous and incremental forms of technical and organizational change; and (iii) provide the human and organizational resources committed to managing and operating the technology and to generating continuous change across the whole spectrum of the technical and organizational system.

A number of experiences with the transfer of new and renewable energy technologies to developing countries have rather been disappointed (Foley, 1992). The lack of self-consistent and articulated structures for supporting and assimilating the technological change has been identified (Bell, 1991) as one of the causes of technological choices that resulted in inappropriate and overextended activities. Concerning the deployment of large-scale wind power farms in Egypt, the natural question to ask is about the existence of a technological innovation system able to adapt the technology to local conditions, operate it at standard efficiency levels, and in the long term increase the share of locally produced equipment.

Ongoing experience with wind power technology in Egypt shows that:

- There exist the human and institutional resources required to plan and manage the organizational environment and operations involved in the use of the technology. The New and Renewable Energy Authority (NREA) has been established to provide the institutional framework for implementing the national strategy on renewable energy development and acting as a focal point for expanding the efforts to large-scale diffusion of renewable energy technologies. The institutional structure of the Egyptian energy sector assures NREA, at least in principle, the necessary conditions to act as a “social carrier” of the wind-energy technology. In other words, NREA is an institution endowed with the social, economic and political mandate (power) to materialize the diffusion and use of renewable energy technologies.
- “Egypt has already crossed the phase of demonstration and pilot projects on wind energy. Currently, a 5 MW grid connected farm in Hurghada is operating successfully” (NREA-RNL, 2001). This shows the existence of local experts who have experience on

understanding and handling the technology and how to operate it under the specific local conditions.

- The establishment of the Wind Energy Technology Centre at Hurghada (NREA-RNL, 2001) represents an important step toward the development of a basic system of technological innovation to support the diffusion of the wind technology across the country. The centre includes full-scale testing and certification facilities in line with the standards and procedures that are specific to Egyptian conditions. This means that the conditions exist for wind turbines to not just operate and maintain standard efficiency levels but also to keep and increase those levels through continuing incremental forms of technical and organizational innovation.

The above remarks show that wind technology's demands in terms of skills, know-how and organizational requirements are compatible with existing and potential capabilities within the country. The risks of a technological choice resulting in an overextended activity are slight. Additionally, the fact that around 45 percent of the value of the equipment in the latest demonstration projects were locally produced (NREA-RNL, 2001) demonstrates the local capability to meet growing industrial demands.

7.5. Contribution of the Project to the Sustainability of the Energy-Economic System

Efficacy of GHG Reduction

Although wind energy technologies pose no environmental problems, they are not free of emissions. The production of blades, the tower, the generator, the transport of equipment, and the construction imply consumption of energy resources. Hence, emissions occur as long as these energy resources are based on fossil fuels. However, only very low GHG emissions are associated with the energy use in the production process. For example, estimations of CO₂ emissions per kWh are around 15 g/kWh for wind turbines under a wind speed of 6.5 m/s, while the equivalent for photovoltaic panels is between 60 and 200 g/kWh (Ackermann et al., 2000; Alsema et al., 2000). A more revealing indicator of CO₂ emissions and of the climate change mitigation potential of the wind technology is the energy payback time calculated by dividing the gross energy requirement for wind turbines production by yearly energy generation during the operation. Under the same wind conditions, the energy payback time has been estimated between 2 and 8 months, a very short period compared to 4 to 5 years in the case of photovoltaic panels. These figures allow one to conclude that wind energy constitutes an efficient strategy to controlling GHG emissions.

Resilience

Egypt depends mainly on oil, natural gas and hydro resources to meet its energy requirements. It has been estimated that around 90 percent of the hydropower potential has already been tapped with the installation of 2.800 MW of power capacity in the complex of High Dam and Aswan Dam (I) & (II) power plants (Gelil et al., 2000). Currently, hydropower accounts for around 21% of total electricity generation, the rest is supplied by oil and natural gas.

The increasing dependency of the Egyptian energy systems on oil and gas natural raises two major problems. First, there are major uncertainties associated with the oil reserves, and Egypt may in the near future become an energy importing country. Second, national revenues from oil

exports are declining as result of the growing domestic consumption. It is clear that the short- and medium-term sustainability of the energy system partly depends on its ability to cope in various ways with the challenges posed by its excessive reliance on oil. These challenges could become even more demanding due to the important share of hydropower in electricity generation. Unpredictable fluctuations in oil prices and in weather conditions could substantially undermine the supporting base for both the operation and future expansions of the electricity system. In the longer term the sustainability of the system depends on its ability to adapt to the prospects of oil reserve decline.

Within this context the wind power technology could play a significant role in increasing the resilience of the energy system to possible shocks. A more diversified resource base raises the system robustness and enhances the freedom of action to cope with periodical fluctuations and changes. Moreover, the diversification of energy sources should be seen as part of a long-term adaptation process of the system to an eventual post-oil energy development.

Technological Diversification

As was noted above, any process of technological innovation opens fresh opportunities for economic interaction. New economic compartments are created, technological clusters tend to appear and hierarchical structures emerge to regulate the network of these new compartments and clusters. As a consequence, the technological and productive base of the society becomes more diversified and interconnected. This process of increase in complexity is the basic condition for economic growth and development of societies (Templet, 1999; Kauffman, 1999).

Related to the diffusion of wind technology in Egypt, the question here is about the existence of the conditions for the technology to activate the kind of network effects mentioned above. This question is pertinent since experience with technology transfer to developing countries show that inappropriate and over-demanding technologies have resulted in technological choices with nil or scant capability growth. In this regard the prospects for the development of a wind-energy technological cluster in Egypt show a significant potential. A progressive local development of wind turbine equipment and know-how, such as generators and controllers, the design and fabrication of towers and blades more adapted to local conditions and resources, and local development of analytical tools for estimating and predicting wind/power as well as optimal power evacuation and grid integration, are some of the clusters that enable the development of indigenous wind/energy technology. Additionally, wind turbine testing and certification, service assistance and continuous training complement the potential multiplier effects of the wind technology on the Egyptian economy.

Environmental Impacts

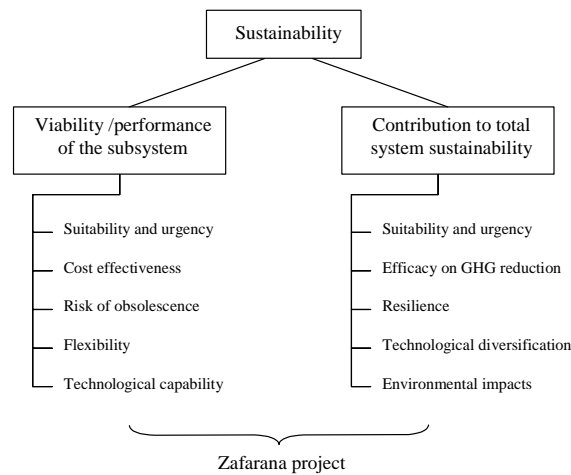
Wind energy is regarded as environmentally friendly. Environmental impacts associated with wind farm installations, such as noise, visual impact, and land use, are meaningless in the case of the Zafarana project. The project is intended to be located in a desert area with no human settles, sparse vegetation, and no activities, such as airports or telecommunication facilities, that could be affected by the wind turbines operation. Contrasting to other situations (India, for example) where rising costs of land constitutes an important barrier for wind turbines deployment, the Zafarana location presents no restrictions on land use. Moreover, the wind farm operation avoids emissions of local pollutants associated with conventional thermal power plants, usually located in the proximity of urban centers.

7.6 Multicriteria Assessment

The preceding discussion shows that the project’s performance is not similar across the different indicators. While the project satisfactorily fulfils, for example, the criteria of suitability and technological capability, the issue of cost-effectiveness remains uncertain. Moreover, each of the indicators has a different weight on the overall sustainability of this specific project. Although the Orientation Theory recognizes that each sustainability dimension stands for a unique requirement, which means that a minimum of attention must be paid to each of them, it is necessary to introduce a hierarchical structure of urgency or prioritization into the analysis. This is mainly to reflect different perspectives on and perceptions of sustainability. For example, private investors would be most concerned about the viability and performance of the project and about issues related to the cost-effectiveness, flexibility and risks of obsolescence. Conversely, issues dealing with the project’s contribution to the resilience and diversification of the electricity supply system would be a priority concern of policy makers.

To account for differences in the indicators’ performance and in project stakeholders’ perspectives on the overall sustainability assessment, a multi-attribute decision-making method has been applied. In this context, the evaluation of the Zafarana project can be represented as a standard decision problem (Figure 16), where sustainability needs to be evaluated according several sub-criteria (indicators). These criteria must be assessed according to their significance for higher order-criteria (viability and contribution to the total system) and the trade-offs among them determine the overall sustainability of the project. Within this framework the project is said to be sustainable if its dynamics never drive it outside the “boundaries” of acceptable values of the criteria.

Figure 20: The sustainability evaluation of the Zafarana project as a multi-attribute decision problem



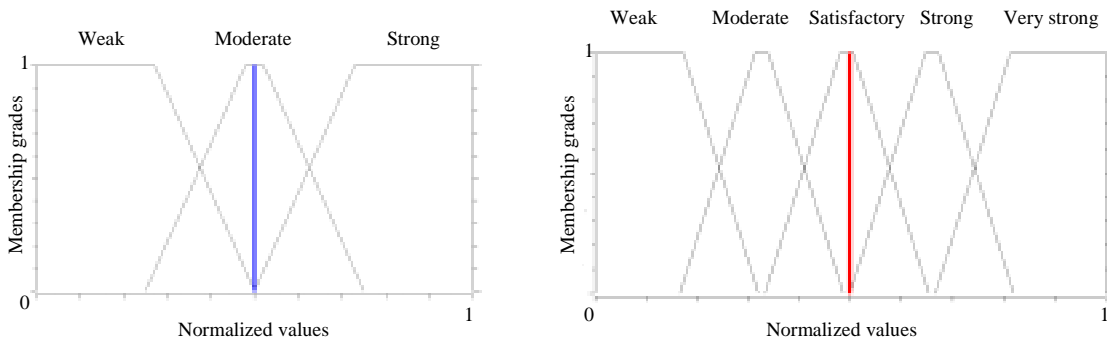
The ambiguity that characterizes the issue of sustainability, the vagueness of the criteria applied, and the uncertainty whether the project satisfies the criteria calls for the use of a fuzzy logic approach to the sustainability assessment (Shu-Jen et al., 1992; Zimmermann, 1993). Fuzzy logic is a mathematical theory for modeling situations in which traditional modeling languages that are dichotomous in character and unambiguous in their description cannot be used. Decisions

concerning sustainable development are not between clear-cut “good” and “bad” alternatives but involve choosing between options that behave in their own way on the different dimensions of sustainability. Human judgments, especially in linguistic form, appear to be unavoidable to characterizing this behavior. A linguistic representation of an observation requires less artificial and complicated transformations than a numerical representation and, therefore, less distortion may be introduced in the former than in the later (Munda, et al, 1994). Fuzzy logic has the ability to deal with complex and polymorphous concepts that are not amenable to a straightforward quantification and contain ambiguities. Reasoning with such ambiguities concepts may not be clear and obvious, but rather fuzzy (Phillis et al, 2001).

Fuzzy logic techniques for multi-attribute assessment deal with linguistic variables. Briefly, a linguistic variable is basically defined by three items, (i) the name of the variable (in the present case the indicators); (ii) its linguistic values (weak, moderate, good, etc.); and (iii) membership functions mapping the linguistic value to a unit interval. Linguistic-based fuzzy rules are used to infer the linguistic values of criteria at the next hierarchical level in the problem structure.

Three linguistic values: weak, moderate, strong have been assigned to the indicators, and trapezoidal membership functions are associated to the variables. The limited number of values is justified here for the practical reason of keeping the problem dimension within manageable margins. Figure 17 shows an example of the membership functions used in the analysis.

Figure 21: Type of membership functions.



For the linguistic variables associated with the viability-performance and the contribution to total system sustainability (see Fig. 1) the following linguistic values are used: weak, moderate, satisfactory, strong and very strong. In this case, five linguistic values allow for a higher flexibility in the analysis of the contribution of these variables to the overall sustainability of the project. For the latter, four variable linguistic values are considered. Fuzzy logic reasoning of type IF-THEN is used to elicit the rule inference base of the analysis. Examples of linguistic-based rules applied are as follows:

IF *Suitability/Urgency* is STRONG
 and *Cost-effectiveness* is LOW
 and *Risk of obsolescence* is MODERATE
 and *Flexibility* is LOW
 and *Technological capability* is LOW
 THEN *Viability* is WEAK.

IF *Viability* is STRONG
 and *Contribution to total system* is SATISFACTORY
 THEN *Sustainability* is ACCEPTABLE.

The definition of inference rules may represent a cumbersome task when a fuzzy logic approach is followed. In the present case the determination of linguistic rules has been facilitated by the monitoring procedures incorporated within the software applied.⁶² The model checks the consistency of the rules and warns the user when an inconsistency is encountered. Additionally, the process of rule base construction was simplified by assuming that the minimal value of one variable (effectiveness) has prominence over the remaining variables. The linguistic rule base for the variable “overall sustainability” is presented in matrix format in Table 16. The linguistic values affected by a modifier (greater than and greater or equal than) were suggested by the DEX model after checking the consistency of previous inputs.

Table 16: Rules matrix for the linguistic variable “sustainability”.

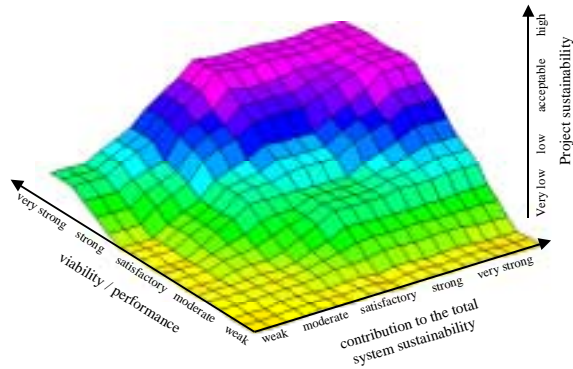
| Contribution to total system → Viability ↓ | <i>Weak</i> | <i>Moderate</i> | <i>Satisfactory</i> | <i>Strong</i> | <i>Very strong</i> |
|---|-------------|-----------------|---------------------|---------------|--------------------|
| <i>Weak</i> | VL | VL | VL | VL | VL |
| <i>Moderate</i> | VL | VL | L | ≥L | ≥L |
| <i>Satisfactory</i> | VL | L | ≥L | >L | A |
| <i>Strong</i> | VL | ≥L | A | ≥A | H |
| <i>Very strong</i> | VL | A | H | H | H |
| VL, very low; L, low; A, acceptable; H, high | | | | | |

A graphical representation of the matrix is provided in Figure 22. The graphic⁶³ can be seen as representing different levels of an output (project sustainability) plotted against combinations of two inputs (viability and contribution to the total system). As can be seen from the figure, the criterion of the viability of the project has been given prominence in the project’s contribution to the sustainability of the energy-economic system. This is quite reasonable considering that the Zafarana project is evaluated here as a potential candidate for the CDM.

⁶² DEX – An Expert System Shell for Multi-Attribute Decision Making. Jozef Stefan Institute; Ljubljana, Slovenia.

⁶³ The graphic was constructed with the aid of the Fuzzy Knowledge Builder software developed by Fuzzy Systems Engineering.

Figure 22: Graphic representation of the linguistic rules.



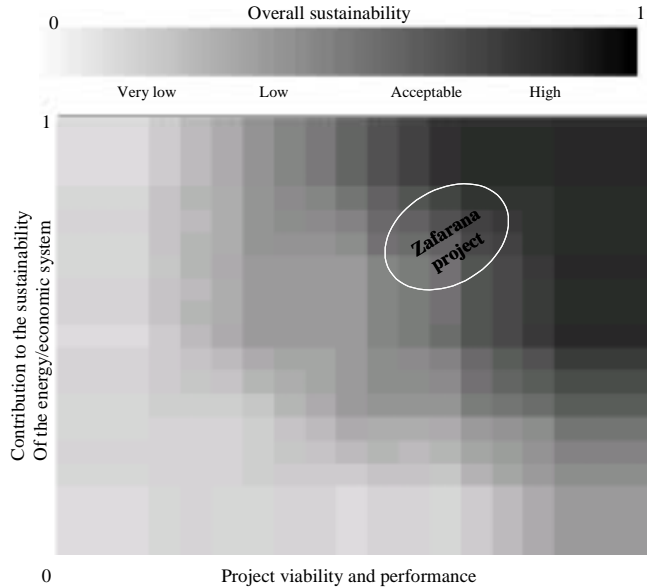
The main results of the analysis are summarized in Table 17. The right column in Table 17 shows the relative standing of the Zafarana project with respect to the primary linguistic variables (indicators) intervening in the assessment. Based on both the membership functions adopted for the criteria and the corresponding linguistic rules, linguistic qualifiers are obtained for the secondary linguistic variables (viability and contribution to the total system). In turn, these qualifiers applied to their corresponding rules allow for a global evaluation of the project performance with respect to the main goal (overall sustainability). This performance is showed in the fuzzy graphic represented in Figure 23.

Table 17: Assessment of the project performance.

| | | | |
|--|------------|--------------|-----------------|
| Overall sustainability | Acceptable | | |
| | High | | |
| Viability | | Satisfactory | |
| — Suitability | | Strong | |
| — Cost effectiveness | | | Strong |
| — Risk of obsolescence | | | Moderate / Weak |
| — Flexibility | | | Weak |
| — Technological capability | | | Strong |
| Contribution to the sustainability of energy-economic system | | | Strong |
| — Suitability | | | Strong |
| — Efficacy on GHG reduction | | | Moderate |
| — Resilience | | | Strong |
| — Technological diversification | | | Strong |
| — Environmental protection | | | Strong |

The fuzzy approach appears to be well suited to provide qualitative answers pertaining to sustainability. Fuzzy logic variables and operations compensate for the ambiguity and lack of full knowledge of the issues on sustainability. Clearly, the presence of a certain subjective component is inevitable in the definition of membership functions and linguistic rules. However, the advantage of the approach is to make clear the degree of subjectivism and to provide means to check the consistency of the users' preferences and reasoning.

Figure 23: Performance of the project on the overall sustainability.



7.7 Conclusions

It is reasonable to conclude that the prospects for the sustainability of the Zafarana project are positive. This is evident from the assessment presented in section 3 and the results from the multi-attribute assessment. From the standpoint of project viability, apart from the uncertainty regarding cost-effectiveness, the other indicators show high favorable conditions for their achievement by the project. Indeed, the project responds to the national development priorities, the risks of economic and technical obsolescence are low, its integration into grid poses no significant problems, and there exist human and institutional resources as well as local expertise to manage and operate the project at standard levels of efficiency.

From an energy sector perspective, Egyptian authorities expect that wind technology would further the achievement of development objectives broader than those confined to techno-economic considerations. Given the size of the Zafarana project relative to the national power supply capacity, the project's contribution to the sustainability of the energy system, and more generally the economic system, is marginal. However, the question of the project's impact on national development goals must be assessed beyond its technical boundaries. Within this context, the Zafarana project must be seen as part of process towards more environmentally sound and diversified energy systems where wind power is called to play a relevant role. In this regard the project effectively satisfies the requirements with respect to resilience, technological diversification, and environmental protection. A significant wind power capacity in the total power supply decreases the power system vulnerability to unexpected contingences and eventual fluctuations of hydrology conditions and oil prices. Moreover, the wind technology could trigger the development of industrial activities with no negligible effects on the diversification of the national technological fabric. Finally, due to its location characteristics, potential negative impacts on the environment, such as land use requirements, noise and visual impacts, are irrelevant.

APPENDIX 3. QUANTIFYING SOCIAL BENEFITS AND COSTS OF CDM PROJECTS: METHODOLOGY AND A CASE STUDY FROM ZAFARANA

Introduction

Various types of benefits related to employment creation, public health, gas exports, and deferred public energy sector investments should be considered in the context of the Zafarana wind park. The magnitude of such secondary or ancillary benefits would be important for a potential host country. These benefits would influence whether a developing country would want to host a CDM project.

This section outlines a general framework for undertaking a quantitative assessment of the social benefits and costs that CDM projects generate in host countries. Because of lack of accurate information and data, the section is not making an in-depth analysis or presenting a precise estimate of the employment effect or other gains created by the wind park in Zafarana. It intends instead to present a methodology and a framework for assessing the socio-economic benefits and costs of CDM projects.

Employment

“First-Cut” Approach

In this section, the impact of the Zafarana wind park on net employment in Egypt is discussed and quantified in a preliminary way. But the primary aim is to present a “first-cut” approach to the analysis of the employment benefits and gains that a 60 MW wind park would generate in a host country.

A net approach should be followed when assessing the amount of employment that a CDM project could generate in a host country. This approach implies that it is only the net or additional amount of employment creation that should be considered and estimated. Obviously, a wind park that only would employ labor already employed elsewhere in the Egyptian economy would not generate any new or additional jobs; it would just transfer labor from one type of employment to another type. Hence, only the employment of workers who were unemployed prior to project commencement should be counted. It is assumed here that Egypt’s current unemployment rate is 18%, twice the official figure.⁶⁴

The following would be the five most important areas of employment created by the wind farm in Zafarana: civil works; erection of mills; transportation; tower production; and operations and maintenance. Table 18 presents information on the duration of employment, the number of workers, and the wages for skilled and unskilled labor for the various types of work.⁶⁵ There would be other activities with a socio-economic impact in the project area, such as income increase for local shopkeepers, hotels, taxi companies, and car rentals. These activities could also be significant for the region, but are difficult to estimate and are not taken into account here.

⁶⁴ See Energy Information Administration, *Egypt* (December 2001): <http://www.eia.doe.gov/cabs/egypt.html>

⁶⁵ This information has been provided by Ibrahim Oezarslan, Nordex.

Table 18: Employment generation by the wind park in Zafarana.

| | <i>Skilled Workers/ Months</i> | <i>Unskilled Workers/ Months</i> | <i>Total Months</i> |
|-------------------|------------------------------------|--------------------------------------|-------------------------|
| Civil works | 5/6 | 25/6 | 180 |
| Erection of mills | 3/18 | 4/18 | 126 |
| Transportation | 16/3 | 8/3 | 72 |
| Tower production | 25/8 | 0/0 | 200 |
| O&M | 20/240 | 15/240 | 8400 |
| Total Months | 5132 | 3846 | 8978 |

The wind park would generate 748.2 man-years of employment in total. A diverse set of tasks related to civil works, erection of mills, transportation, and tower production would be performed in the early phases. Yet, these activities would only amount to 48.2 man-years—or around 6.5 per cent of the total employment generated. By far the largest amount of employment—700 man-years—would be generated by the operation and maintenance work on the wind park. This relatively large amount of employment is due, first, to the relatively high number of workers involved and, second, to the fact that the operations and maintenance work would be spread over the entire 20 years’ life of the wind park.

As shown in Table 19, there are significant differences between the wages of skilled and unskilled labor across the different job categories.⁶⁶ Workers involved in the erection of mills would be paid the highest salaries, whereas workers involved in the operation and maintenance work would receive the lowest salaries.

Table 19: Income generated by the wind farm in Zafarana.

| | <i>Civil works</i> | <i>Erection of Mills</i> | <i>Transportation</i> | <i>Tower Production</i> | <i>O&M</i> |
|------------------------------|--------------------|------------------------------|-----------------------|-----------------------------|----------------|
| Unskilled workers | 25 | 4 | 8 | 0 | 15 |
| Skilled workers | 5 | 3 | 16 | 25 | 20 |
| Months Employed | 6 | 18 | 3 | 8 | 240 |
| Monthly wages/ unskilled, E£ | 300 | 800 | 300 | n.a. | 200 |
| Monthly wages/skilled, E£ | 800 | 1,500 | 900 | 750 | 600 |
| Total, US\$ | 15,180 | 30,492 | 11,088 | 33,000 | 792,000 |

n.a.=non applicable.

Using average salaries and a 0.22 conversion rate for E £/US \$, the sum of the wages over the entire life of the wind park is US\$ 881,760. Assuming an unemployment rate of 18%, the value of the net employment created by the wind park would be about US\$ 160,000.

The “first-cut approach” makes a quick, order-of-magnitude estimate of the socio-economic benefit in the form of employment in the host country created by a CDM project. The project developer would collect the information and data necessary for the social cost analysis when preparing the project feasibility study. This information and data could also be made available to the host country.

⁶⁶ This information has been provided by Ibrahim Oezarslan, Nordex.

Comprehensive Approach

It is of course possible to apply a more comprehensive framework when estimating the economic costs and benefits related to the employment created by CDM projects.⁶⁷ This framework covers at least some of the major indirect social benefits and costs. These costs and benefits are not properly reflected in market prices and market transactions and, thus, do not appear in a standard cost statement. The data and information that are needed for the assessment will usually not be readily available to the project developed or to the host country. But if the results from the “first-cut” approach are encouraging, it seems quite useful to make a more comprehensive assessment of the social benefits of the employment generated by a CDM project.

First, in addition to the income to workers generated by the project, this approach takes into account the employment benefits that unemployed workers would lose when employed.

Second, it also takes into account that the “free” time that unemployed workers have is valuable in an economic sense since it may often be possible for unemployed workers to engage in alternative activities creating economic value, e.g., in own production, house repair and maintenance, etc. The economic value of the “non-working time” can be expressed as a percent, or a ratio, of the value of the working time. The latter is reflected in the wage received by workers when they are in employment.

Third, unemployment can often result in an unhealthy and unsatisfactory social situation which entails an increased mortality risk compared to the employed population. Thus, it seems appropriate to include the health benefits of employment in terms of a reduced risk of death. It is here assumed that the risk of death among unemployed is 4.5 workers per 1,000 workers.⁶⁸ Consequently, employing one person would reduce this risk of death by 4.5/1000.

The assumptions behind the more comprehensive approach lead to a definition, and a calculation, of social welfare gains as follows:

- (1) the net gain of income to the individual as a result of the new job, allowing for possible employment benefit, informal employment, etc. In this case, the net of tax wages should not be used in calculations as the workers employed in the Zafarana project would be exempted from paying tax; minus
- (2) the value of the non-working time the person had when unemployed and which is lost when being employed. It is assumed here that the value of non-working time is 15 percent of the gross wage; plus
- (3) the value of the health-related implications of being unemployed, which are avoided when being employed. As mentioned it is assumed that the excess death rate among the unemployed is 4.5 deaths per 1,000 men.

To estimate the social benefits, one multiplies the welfare costs (1) minus (2) plus (3) by the period of employment created by the CDM project.

⁶⁷ See Alistair Hunt, Pamela Mason, and A. Markandya, “Measuring the Indirect Costs and Benefits of Greenhouse Gas Mitigation Options: Methodology and Case Study from Hungary”. FEEM Nota di Lavoro. October 1999; A. Markandya, *The Indirect Costs and Benefits of Greenhouse Gas Limitations* (Risoe, Denmark: UNEP Collaborating Centre on Energy and Environment, 1998).

⁶⁸ It will evidently be important to base calculations on the best available knowledge and data.

The approach is illustrated below in the context of Zafarana. First, the implications of taking into account the loss of unemployment benefits and the non-working time are calculated. Next, the value of the positive health-related implications of employment is calculated.

In Egypt the unemployment benefits constitute 60% of last month's wage and may be paid up to 16 weeks, or 3.5 months.⁶⁹ The figures for the unemployment benefits and the value of the non-working time are given in Table 20.

Table 20: Value of unemployment benefits and non-working time of a 60 MW wind park in Egypt.

| | <i>Civil works</i> | <i>Erection of Mills</i> | <i>Transportation</i> | <i>Tower Production</i> | <i>O&M</i> |
|---|--------------------|--------------------------|-----------------------|-------------------------|----------------|
| Unskilled workers | 25 | 4 | 8 | 0 | 15 |
| Skilled workers | 5 | 3 | 16 | 25 | 20 |
| Months employed | 6 | 18 | 3 | 8 | 240 |
| Unemployment Benefits. Unskilled Workers (E£) | | | | | |
| Monthly in 1-3½ months | 180 | 480 | 180 | n.a. | 120 |
| Monthly > 3½ months | 0 | 0 | n.a. | n.a. | 0 |
| Sub-total | 15,750 | 6,720 | 4,320 | n.a. | 6,300 |
| Unemployment Benefits. Skilled Workers (E£) | | | | | |
| Monthly in 1-3½ months | 480 | 900 | 540 | 450 | 360 |
| Monthly > 3½ months | 0 | 0 | n.a. | 0 | 0 |
| Sub-total | 8,400 | 9,450 | 25,920 | 39,375 | 25,200 |
| Total: All workers | 24,150 | 16,170 | 30,240 | 39,375 | 31,500 |
| Value of Non-Working Time (E£) | | | | | |
| Unskilled workers, month | 45 | 120 | 45 | n.a. | 30 |
| Sub-total | 6,750 | 8,640 | 1,080 | n.a. | 108,000 |
| Skilled workers | 120 | 225 | 135 | 113 | 90 |
| Sub-total | 3,600 | 12,150 | 6,480 | 22,600 | 432,000 |
| Total: All workers | 10,350 | 20,790 | 7,560 | 22,600 | 540,000 |
| Total: All Workers (E£) | | | | | |
| Total: All workers | 34,500 | 36,960 | 37,800 | 61,975 | 571,500 |

With the same unemployment rate and conversion rate for E £/US \$ as above, the sum of the unemployment benefits is about US\$ 5,601 and the sum of the value of the lost non-working time is about US\$ 23,811. Thus, the total value is about US\$ 29,413.

Next follows an illustration of the approach to the assessment of the value of the health-benefits of employment. It should be stressed that this estimate is made purely for the sake of illustration. Certainly, it might be preferable to present quantitative data—i.e., the number of human lives saved—instead of monetary values. Valuation of human life and international comparison of the economic value of human life is made very difficult by the lack of well-established and widely accepted methods and tools for such purposes. Furthermore, few studies of the willingness-to-pay and the economic value of human life have been carried out in developing countries that host countries could build upon.

It is assumed that the economic value of life in Egypt is E £ 2.86 million.⁷⁰ Based on the assumption that employment reduces the rate of death by 4.5/1000, the health benefit per person per year is:

⁶⁹ Unemployment benefits may be extended to 28 weeks if contributions were paid throughout the last 24 months. It is assumed that this does not apply in this case. See, *Social Security Programs Throughout the World, 1999-Egypt*. <http://www.ssa.gov/statistics/ssptw/1999/English/egypt.htm>

E £ 2.86 million * 4.5/1000 = E £ 12,870.

Table 21: Health benefits of employment generated by a 60 MW wind park in Egypt.

| | <i>Monthly benefit, (E£)</i> | <i>Months</i> | <i>Total benefits, (E£)</i> |
|-------------------|------------------------------|---------------|-----------------------------|
| Civil works | 1,073 | 180 | 193,140 |
| Erection of mills | 1,073 | 126 | 135,198 |
| Transportation | 1,073 | 72 | 77,256 |
| Tower production | 1,073 | 200 | 214,600 |
| O&M | 1,073 | 8400 | 9,013,200 |

It is again assumed that the unemployment rate is 18%. With the same conversion rate as above, the health benefits amount to about US\$ 381,482.

Using the more comprehensive approach, the total sum of the social benefits to Egypt created by the wind park in Zafarana would be about US\$ 512,133 (US\$ 160,000 – (US\$ 5,601 + US\$ 23,748) + US\$ 381,482). By counting the benefits and costs related to the employment benefits, the non-working time, and the health benefits of employment, the total sum of the benefits of employment increases by around 320 per cent.

Health

The wind park in Zafarana would also create health and environmental benefits because it would mean avoidance of emissions of local pollutants with negative health effects. The host country, Egypt, would also accrue the secondary or ancillary benefits which would occur as a result of displacement of fossil fuels that emit non-greenhouse gases, such as sulphur dioxide (SO₂), oxides of nitrogen (NO_x), and particulate matter.⁷¹

The amounts and types of ancillary benefits would depend on the fuel mix that would be displaced by the wind park. In other words, the baseline—an issue that is extensively discussed in chapters 3-5—and the base case technology and fuel would be key. Given the state of the international rules on baseline methodologies at this point, different baselines may be relevant in this case and the secondary benefits would vary with the underlying baseline. But the analytical steps to be followed would be similar for all baseline scenarios:

- 1) The amount and type of fuel that would be avoided should be calculated. In this context, the simplest baseline scenario would be one which assumed that the wind park would displace a specific power plant. The technology that attracted the most recent foreign direct investment in Egypt could be selected as the base case technology against which the wind farm should be compared.⁷² With a capacity factor of 48.8% for the Zafarana

⁷⁰ For a discussion of the value of a statistical life (VOSL) and an illustrative Egyptian example, see A. Markandya, *The Indirect Costs and Benefits of Greenhouse Gas Limitations* (Risoe, Denmark: UNEP Collaborating Centre on Energy and Environment, 1998), p. 31.

⁷¹ For a recent collection of studies, see OECD, *Ancillary Benefits and Costs of Greenhouse Gas Mitigation* (Paris, France: OECD, 2000).

⁷² Sidi Krir 3 & 4, which is located thirty kilometers west of Alexandria, is the first privately built and operated large-scale generating facility in Egypt. This natural gas-steam powered plant with 682 MW of capacity could well serve as the appropriate base case plant for comparative purposes.

- wind park, it would be necessary to install about 37 MW of gas thermal.⁷³ Information on the fuel type and plant efficiency should be used in calculating the total consumption of fossil fuels that would be displaced by the wind park.
- 2) The amount of local pollutants could be estimated by multiplying the amount of fuel with the calorific value and the emission factors for the fuel. This would give the amounts of sulphur dioxide (SO₂), oxides of nitrogen (NO_x) and other air pollutants that would be avoided by the wind park.
 - 3) The third step would concern the local dispersion of the air pollutants. The specific geographic location of the power plant would have to be considered. Obviously, the exposure of the population would depend on whether it would be assumed that the power plant would be located in an urban area or in a sparsely populated area. The local dispersal pattern for air pollutants would also have to be considered.
 - 4) The fourth step would focus on the recipients who would be exposed to the air pollutants. Information on the density, gender, age profile etc. of the exposed population would be needed to estimate the health impacts caused by the air pollutants. The estimate would quantify the mortality and morbidity implications of the exposure to the air pollutions, thus producing quantitative figures for the public health benefits achieved by avoiding the air pollution emissions.
 - 5) In the final step, it is possible to monetize the reduced mortality and morbidity rates due to the wind park. This step involves assessment of the value of a statistical life, and indirectly of the willingness-to-pay for avoiding loss of human life, in the context of Egypt.

Foreign Currency Earnings

Egypt will probably become a major exporter of natural gas by the middle of the current decade. Accordingly, since the wind park would make it possible to save natural gas which could be sold abroad, the wind park could increase Egypt's foreign currency earnings.

The natural gas could likely be sold in the regional gas market at a price exceeding the current domestic gas price. Natural gas is currently priced at about US\$ 1.12/MMBTU for power generation in Egypt, but long-term LNG export contracts could value the gas at a higher level, possibly between \$2 and \$3/MMBTU.⁷⁴ As well, access to the regional market would probably raise the gas price in the market in Egypt.

Although different baselines are possible, the following steps assume that the wind park would displace a power plant fired by natural gas:

- 1) The amount of natural gas saved as a result of the CDM wind park should be calculated. This step is similar to the first step in calculating the health benefits above; and
- 2) Second, the amount of natural gas saved should be multiplied by the gas price. To correct for the price distortions caused by energy taxes and subsidies, it is recommended to use international gas price.

⁷³ With a capacity factor of 48.8% each kW of wind will be capable of producing 4,275 kWh per year, compared to a typical value of about 7,000 kWh/year/kW for new thermal plants (Swaminathan and Fankhauser, 2000, p. 178). Thus, in order to displace 60 MW of wind power capacity, about 37 MW ($60 \times 4,275 / 7,000$) of thermal power plant capacity would have to be installed.

⁷⁴ See GEF, "Proposed Program Concept and Request for a PDF Block B Grant", p. 4. April 12, 2001.

A major difficulty here is that estimates of future prices of exported goods generated by a wind power project can be quite uncertain. The same is true of future prices of imported goods and services replaced by a wind project.

The type of benefits that a wind park would create depends on the conditions that characterize the host country and the power sector. For instance, whereas a wind farm project in Egypt could lead to increased export of fuel that would have otherwise been consumed by Egypt, a wind farm may under different conditions reduce the need for importing fuel for electricity production purposes.

ANNEX 1.

Table 22: List of all power plants in Egypt. 1999/2000.

| Power Station | No. of units | Installed capacity (MW) | Fuel type | Commissioning date | Gross generation (GWh) | Net generation (GWh) | Fuel consumption rate (g/KWh) | Peak load (MW) | Load factor (%) | Efficiency (%) |
|------------------------|--------------|-------------------------|------------|--------------------|------------------------|----------------------|-------------------------------|----------------|-----------------|----------------|
| Shoubra (st) | 4x315 | 1260 | HFO/NG | 1984-85-88 | 7410 | 7100 | 225.8 | 1195 | 71 | 38.8 |
| Cairo West (st) | 4x87.5 | 350 | HFO/NG | 1966-79 | 1722 | 1618 | 252.2 | 348 | 56 | 34.8 |
| Cairo West (ext) | 2x330 | 660 | HFO/NG | 1995 | 3277 | 3178 | 217.9 | 660 | 57 | 40.3 |
| Cairo South (c.c. 1) | 3x110+4x60 | 570 | NG/HFO/LFO | 57-65-1989 | 3173 | 3101 | 224.5 | 528 | 68 | 39.1 |
| Cairo South (c.c. 2) | 1x110+1x55 | 165 | LFO/NG | 1995 | 1154 | 1134 | 184.3 | 174 | 75 | 47.6 |
| Wadi Hof (gas) | 3x33.3 | 100 | LFO/NG | 1985 | 107 | 106 | 383.4 | 92 | 13 | 22.9 |
| El Tebbin (gas) | 2x23 | 46 | LFO/NG | 1979 | 53 | 53 | 358.6 | 40 | 15 | 24.5 |
| El Tebbin (st) | 3x15 | 45 | HFO | 1958-59 | 224 | 229 | 374.7 | 42 | 67 | 23.4 |
| Demietta (c.c.) | 9x125 | 1125 | LFO/NG | 1989-93 | 7379 | 7275 | 183.6 | 1185 | 71 | 47.8 |
| Talkha (c.c.) | 8x24.2+2x45 | 283.6 | LFO/NG | 1979-80-89 | 1353 | 1329 | 243 | 283 | 54 | 36.1 |
| Talkha (st) | 3x30 | 90 | HFO | 1966-67 | 35 | 29 | 426.3 | 33 | 12 | 20.6 |
| Talkha (210) (st) | 2x210 | 420 | HFO/NG | 1993-95 | 2247 | 2083 | 240.9 | 421 | 61 | 36.4 |
| Kafr El Dawar (st) | 4x110 | 440 | HFO/NG | 1980-84-86 | 1788 | 1665 | 263.1 | 310 | 65 | 33.3 |
| Mahmoudia (gas) | 4x45 | 180 | LFO/NG | 1981-82 | 89 | 89 | 361.7 | 149 | 7 | 24.3 |
| Mahmoudia (c.c.) | 8x24.5+2x56 | 308 | LFO/NG | 1983-95 | 1568 | 1548 | 207.9 | 312 | 57 | 42.2 |
| Damanhour (300) (st) | 1x300 | 300 | HFO/NG | 1991 | 1614 | 1564 | 217 | 300 | 61 | 40.4 |
| New Damanhour (st) | 3x65 | 195 | HFO/NG | 1968-69 | 693 | 651 | 258.1 | 192 | 41 | 34 |
| Old Damanhour (st) | 2x15 | 30 | HFO | 1960 | NA ¹ | NA | NA | NA | NA | NA |
| Damanhour (c.c.) | 4x24.2+1x56 | 152,8 | LFO/NG | 1985-95 | 849 | 838 | 193.2 | 155 | 63 | 45.4 |
| El Siuf (gas) | 6x33.3 | 200 | LFO/NG | 81-82-83-84 | 251 | 249 | 378.8 | 100 | 29 | 23.2 |
| El Siuf (st) | 2x26.5+2x30 | 113 | HFO | 1961-69 | 516 | 480 | 309.3 | 80 | 74 | 28.4 |
| Karmouz (gas) | 2x12.5 | 25 | LFO | 1980 | 1 | 1 | 421.6 | 9 | 11 | 20.8 |
| Table 22 continued ... | | | | | | | | | | |
| Power Station | No. of units | Installed | Fuel type | Commissioning | Gross | Net generation | Fuel | Peak | Load | Efficiency |

| | | capacity (MW) | | date | generation (GWh) | (GWh) | consumption rate (g/KWh) | load (MW) | factor (%) | (%) |
|-----------------|----------------|------------------|--------|------------|---------------------|-------|--------------------------------|--------------|---------------|------|
| Abu Kir (st) | 4x150+1x300 | 900 | HFO/NG | 1983-84-91 | 4299 | 3992 | 227.2 | 897 | 55 | 38.6 |
| Sidi Krir (st) | | | | | 1206 | 1138 | 226.3 | 610 | 22 | 38.8 |
| Akata (st) | 2x150+2x300 | 900 | HFO/NG | 1985-87-86 | 5528 | 5257 | 214.6 | 900 | 70 | 40.9 |
| Abu Sultan (st) | 4x150 | 600 | HFO/NG | 1983-84-86 | 2932 | 2705 | 250 | 589 | 57 | 35.1 |
| Suez (st) | 4x22+1x97 | 185 | HFO | 1965-91 | 478 | 425 | 294.8 | 118 | 46 | 29.8 |
| El Shabab (gas) | 3x33.3 | 100 | LFO/NG | 1982 | 119 | 119 | 346.8 | 88 | 16 | 25.3 |
| Port Said (gas) | 1x21+1x23+1x20 | 64 | LFO/NG | 1984-1977 | 35 | 34 | 374.6 | 42 | 10 | 23.4 |
| Arish | 2x33 | 66 | HFO | 2000 | 253 | 227 | 297.2 | 66 | 44 | 29.5 |
| Zafarana (wind) | 31x0.6 | 19 | Wind | 2000 | | | | | | |
| Walidia (st) | 2x300 | 600 | HFO | 1992-1997 | 2649 | 2504 | 228.4 | 612 | 49 | 38.4 |
| Korimat (st) | 2x627 | 1254 | HFO/NG | 1999 | 5068 | 4884 | 218.6 | 1180 | 49 | 40.1 |
| Assiut (st) | 3x30 | 90 | HFO | 1966-67 | 538 | 484 | 290.6 | 90 | 68 | 30.2 |
| High Dam | 12x175 | 2100 | Hydro | 1967 | 10889 | 10723 | | 1980 | 63 | 85.1 |
| Aswan Dam 1 | 7x40 | 280 | Hydro | 1960 | 1549 | 1509 | | 265 | 66 | 83.2 |
| Aswan Dam 2 | 4x67.5 | 270 | Hydro | 1985-86 | 1850 | 1843 | | 270 | 78 | 90.8 |
| Esna | 6x15 | 90 | Hydro | 1995 | 352 | 347 | | 82 | 49 | 82.0 |
| Nag Hammadi | 3x1.7 | 5 | Hydro | 1942 | 19 | 19 | | 5 | 40 | 84.8 |
| | | | | | | | | | | |
| Total Thermal | | | | | 58628 | 56089 | 225.6 | 9394 | 71 | 38.9 |
| Total Hydro | | | | | 14659 | 14441 | | 2559 | 65 | 85.5 |
| Total Wind | | | | | 23 | 22 | | 17 | 18 | |

Source: Appendix G of the report “Pre-feasibility Study for a Pilot CDM Project for a Wind Farm in Egypt, New and Renewable Energy Agency, Egypt, and RISØ National Laboratory, 2001”. The data supplied by New and Renewable Energy Authority (NREA) and Egyptian Electricity Holding Company (EEHC).

Note: 1. NA = not available.

Table 23: Top 20 per cent plants (least consumption of fuel/GWh) in Egypt using oil and gas fuels^a

| Power Station | Commissioning date | Fuel type | Gross generation (GWh) | Fuel consumption rate (g/KWh) | HFO fraction | HFO used (tons) | NG used (tons) | Carbon emissions (tons) |
|---|--------------------|-----------|------------------------|-------------------------------|--------------|-----------------|----------------|-------------------------|
| Cairo West (ext.) | 1995 | HFO/NG | 3,277 | 217.9 | 0.3 | 214,217 | 499,841 | 539,839 |
| Cairo South (c.c. 2) | 1995 | LFO/NG | 1,154 | 184.3 | 0 | 0 | 212,682 | 153,179 |
| Demietta (c.c.) | 1989-95 | LFO/NG | 7,379 | 183.6 | 0 | 0 | 1,354,784 | 975,748 |
| Mahmoudia (c.c.) | 1993-95 | LFO/NG | 1,568 | 207.9 | 0 | 0 | 325,987 | 234,784 |
| Damanhour (300) (st) | 1991 | HFO/NG | 1,614 | 217 | 0.3 | 105,071 | 245,167 | 264,785 |
| Damanhour (c.c.) | 1985-95 | LFO/NG | 849 | 193.2 | 0 | 0 | 164,027 | 118,136 |
| Akata (st) | 1985-87 | HFO/NG | 5,528 | 214.6 | 0.3 | 355,893 | 830,416 | 896,868 |
| Total | | | 21,369 | | | 675,181 | 3,632,904 | 3,183,339 |
| Average Emissions (C tons /GWh ^b) | | | | | | | | 148.97 |

a. Historical-Top 20 per cent using HFO, NG, LFO or a mix of these fuels (i.e., all plants excluding hydro)

Table 24: Historical/all plants.

| Power Station | Fuel type | Gross generation (GWh) | Fuel consump. rate (g/KWh) | HFO fraction | HFO used (tons) | NG used (tons) | Carbon emissions (tons) |
|----------------------|------------|------------------------|----------------------------|--------------|-----------------|----------------|-------------------------|
| Shoubra (st) | HFO/NG | 7410 | 225.8 | 0.3 | 501953 | 1171225 | 1389937 |
| Cairo West (st) | HFO/NG | 1722 | 252.2 | 0.3 | 130287 | 304002 | 360771 |
| Cairo West (ext) | HFO/NG | 3277 | 217.9 | 0.3 | 214217 | 499841 | 593180 |
| Cairo South (c.c. 1) | NG/HFO/LFO | 3173 | 224.5 | 0.3 | 213702 | 498637 | 591752 |
| Cairo South (c.c. 2) | LFO/NG | 1154 | 184.3 | 0 | 0 | 212682 | 175875 |
| Wadi Hof (gas) | LFO/NG | 107 | 383.4 | 0 | 0 | 41024 | 33924 |
| El Tebbin (gas) | LFO/NG | 53 | 358.6 | 0 | 0 | 19006 | 15717 |
| El Tebbin (st) | HFO | 224 | 374.7 | 1 | 83933 | 0 | 70464 |
| Demiatta (c.c.) | LFO/NG | 7379 | 183.6 | 0 | 0 | 1354784 | 1120326 |
| Talkha (c.c.) | LFO/NG | 1353 | 243 | 0 | 0 | 328779 | 271881 |
| Talkha (st) | HFO | 35 | 426.3 | 1 | 14921 | 0 | 12526 |
| Talkha (210) (st) | HFO/NG | 2247 | 240.9 | 0.3 | 162391 | 378912 | 449669 |
| Kafr El Dawar (st) | HFO/NG | 1788 | 263.1 | 0.3 | 141127 | 329296 | 390788 |
| Mahmoudia (gas) | LFO/NG | 89 | 361.7 | 0 | 0 | 32191 | 26620 |
| Mahmoudia (c.c.) | LFO/NG | 1568 | 207.9 | 0 | 0 | 325987 | 269572 |
| Damanhour (300) (st) | HFO/NG | 1614 | 217 | 0.3 | 105071 | 245167 | 290949 |
| New Damanhour (st) | HFO/NG | 693 | 258.1 | 0.3 | 53659 | 125204 | 148585 |
| Old Damanhour (st) | HFO | | | 1 | 0 | 0 | 0 |
| Damanhour (c.c.) | LFO/NG | 849 | 193.2 | 0 | 0 | 164027 | 135640 |
| El Siuf (gas) | LFO/NG | 251 | 378.8 | 0 | 0 | 95079 | 78625 |
| El Siuf (st) | HFO | 516 | 309.3 | 1 | 159599 | 0 | 133988 |
| Karmouz (gas) | LFO | 1 | 421.6 | | 422 | 0 | 354 |
| Abu Kir (st) | HFO/NG | 4299 | 227.2 | 0.3 | 293020 | 683713 | 811389 |
| Sidi Krir (st) | | 1206 | 226.3 | 0.3 | 81875 | 191042 | 226717 |
| Akata (st) | HFO/NG | 5528 | 214.6 | 0.3 | 355893 | 830416 | 985487 |
| Abu Sultan (st) | HFO/NG | 2932 | 250 | 0.3 | 219900 | 513100 | 608916 |

| Table 24 continued... | | | | | | | |
|---------------------------------|-----------|------------------------|----------------------------|--------------|-----------------|----------------|-------------------------|
| Power Station | Fuel type | Gross generation (GWh) | Fuel consump. rate (g/KWh) | HFO fraction | HFO used (tons) | NG used (tons) | Carbon emissions (tons) |
| Suez (st) | HFO | 478 | 294.8 | 1 | 140914 | 0 | 118302 |
| El Shabab (gas) | LFO/NG | 119 | 346.8 | 0 | 0 | 41269 | 34127 |
| Port Said (gas) | LFO/NG | 35 | 374.6 | 0 | 0 | 13111 | 10842 |
| Arish | HFO | 253 | 297.2 | 1 | 75192 | 0 | 63126 |
| Zafarana (wind) | Wind | | | | | | 0 |
| Walidia (st) | HFO | 2649 | 228.4 | 1 | 605032 | 0 | 507942 |
| Korimat (st) | HFO/NG | 5068 | 218.6 | 0.3 | 332359 | 775505 | 920321 |
| Assiut (st) | HFO | 538 | 290.6 | 1 | 156343 | 0 | 131254 |
| High Dam | Hydro | 10889 | | | | | |
| Aswan Dam 1 | Hydro | 1549 | | | | | |
| Aswan Dam 2 | Hydro | 1850 | | | | | |
| Esna | Hydro | 352 | | | | | |
| Nag Hammadi | Hydro | 19 | | | | | |
| Total | | 73267 | | | 4041810 | 9173999 | 10979568 |
| Average Emissions (C tons /GWh) | | | | | | | 149,86 |

Table 25: Calorific values used.

| Net Cal. Value | (TJ/000 ton) | C (t C/TJ) | Fraction oxidized | Conversion factor tC/000t |
|-----------------|--------------|------------|-------------------|---------------------------|
| HFO | 40.19 | 21.1 | 0.99 | 839.5289 |
| LFO | 43.33 | 20.2 | 0.99 | 866.5133 |
| NG ^a | 54.32 | 15.3 | 0.995 | 826.9405 |

a. For NG, values are not given in IPCC. Natural gas has a value of about 39MJ/cum and a density of 0.718 kg/cum.

This gives $39/0.718 = 54.32$ TJ/th tons as calorific value.

Note: Data available from Egypt gives only one figure for fuel consumption (g/KWh) for the HFO/NG power plants. Since variation in carbon coefficient (about 840 C t/th. ton for oil and 827 C ton/th. ton for NG) is not large, assumption about ratio of HFO and NG used in the plant may change the carbon emissions only marginally. Based on consumption data of HFO and NG, all HFO/NG plants were assumed to use HFO and NG in 30:70 ratio. Egyptian experts confirmed this.

Table 26: Historical/all plants excluding renewable (hydro).

| Power Station | Fuel type | Gross generation (GWh) | Fuel consump. rate (g/KWh) | HFO fraction | HFO used (tons) | NG used (tons) | Carbon emissions (tons) |
|----------------------|------------|------------------------|----------------------------|--------------|-----------------|----------------|-------------------------|
| Shoubra (st) | HFO/NG | 7410 | 225.8 | 0.3 | 501953 | 1171225 | 1389937 |
| Cairo West (st) | HFO/NG | 1722 | 252.2 | 0.3 | 130287 | 304002 | 360771 |
| Cairo West (ext) | HFO/NG | 3277 | 217.9 | 0.3 | 214217 | 499841 | 593180 |
| Cairo South (c.c. 1) | NG/HFO/LFO | 3173 | 224.5 | 0.3 | 213702 | 498637 | 591752 |
| Cairo South (c.c. 2) | LFO/NG | 1154 | 184.3 | 0 | 0 | 212682 | 175875 |
| Wadi Hof (gas) | LFO/NG | 107 | 383.4 | 0 | 0 | 41024 | 33924 |
| El Tebbin (gas) | LFO/NG | 53 | 358.6 | 0 | 0 | 19006 | 15717 |
| El Tebbin (st) | HFO | 224 | 374.7 | 1 | 83933 | 0 | 70464 |
| Demietta (c.c.) | LFO/NG | 7379 | 183.6 | 0 | 0 | 1354784 | 1120326 |
| Talkha (c.c.) | LFO/NG | 1353 | 243 | 0 | 0 | 328779 | 271881 |
| Talkha (st) | HFO | 35 | 426.3 | 1 | 14921 | 0 | 12527 |
| Talkha (210) (st) | HFO/NG | 2247 | 240.9 | 0.3 | 162391 | 378912 | 449670 |
| Kafr El Dawar (st) | HFO/NG | 1788 | 263.1 | 0.3 | 141127 | 329296 | 390788 |
| Mahmoudia (gas) | LFO/NG | 89 | 361.7 | 0 | 0 | 32191 | 26620 |
| Mahmoudia (c.c.) | LFO/NG | 1568 | 207.9 | 0 | 0 | 325987 | 269572 |
| Damanhour (300) (st) | HFO/NG | 1614 | 217 | 0.3 | 105071 | 245167 | 290949 |
| New Damanhour (st) | HFO/NG | 693 | 258.1 | 0.3 | 53659 | 125204 | 148585 |
| Old Damanhour (st) | HFO | | | 1 | 0 | 0 | 0 |
| Damanhour (c.c.) | LFO/NG | 849 | 193.2 | 0 | 0 | 164027 | 135641 |
| El Siuf (gas) | LFO/NG | 251 | 378.8 | 0 | 0 | 95079 | 78625 |
| El Siuf (st) | HFO | 516 | 309.3 | 1 | 159599 | 0 | 133988 |
| Karmouz (gas) | LFO | 1 | 421.6 | | 0 | 422 | 349 |
| Abu Kir (st) | HFO/NG | 4299 | 227.2 | 0.3 | 293020 | 683713 | 811389 |
| Sidi Krir (st) | | 1206 | 226.3 | 0.3 | 81875 | 191042 | 226717 |
| Akata (st) | HFO/NG | 5528 | 214.6 | 0.3 | 355893 | 830416 | 985487 |

| Table 26 continued... | | | | | | | |
|--------------------------------|-----------|------------------------|----------------------------|--------------|-----------------|----------------|-------------------------|
| Power Station | Fuel type | Gross generation (GWh) | Fuel consump. rate (g/KWh) | HFO fraction | HFO used (tons) | NG used (tons) | Carbon emissions (tons) |
| Abu Sultan (st) | HFO/NG | 2932 | 250 | 0.3 | 219900 | 513100 | 608916 |
| Suez (st) | HFO | 478 | 294.8 | 1 | 140914 | 0 | 118301 |
| El Shabab (gas) | LFO/NG | 119 | 346.8 | 0 | 0 | 41269 | 34127 |
| Port Said (gas) | LFO/NG | 35 | 374.6 | 0 | 0 | 13111 | 10842 |
| Arish | HFO | 253 | 297.2 | 1 | 75192 | 0 | 63126 |
| Zafarana (wind) | Wind | | | | 0 | 0 | 0 |
| Walidia (st) | HFO | 2649 | 228.4 | 1 | 605032 | 0 | 507942 |
| Korimat (st) | HFO/NG | 5068 | 218.6 | 0.3 | 332359 | 775505 | 920321 |
| Assiut (st) | HFO | 538 | 290.6 | 1 | 156343 | 0 | 131254 |
| High Dam | Hydro | 10889 | | | | | |
| Aswan Dam 1 | Hydro | 1549 | | | | | |
| Aswan Dam 2 | Hydro | 1850 | | | | | |
| Esna | Hydro | 352 | | | | | |
| Nag Hammadi | Hydro | 19 | | | | | |
| Total | | 58608 | | | 4041388 | 9174421 | 10979563 |
| Average emissions (Ctons /GWh) | | | | | | | 187.3 |

Table 27: Last five years of additions/top 20 percent/all fuels.

| Power station | No. Units | Comm. Date | Gross generation (GWh) | Fraction commissioned | | Fuel type | Fuel cons. rate (G/KWh) | HFO fraction | HFO used (tons) | NG used (tons) | Carbon emissions (tons) |
|--------------------------------|-------------|------------|------------------------|-----------------------------|--|-----------|-------------------------|--------------|-----------------|----------------|-------------------------|
| | | | | 1995 and later ^a | Adjusted generation ^b (GWh) | | | | | | |
| Cairo west (ext.) | 2*330 | 1995 | 3277 | 1 | 3277 | HFO/NG | 217.9 | 0.3 | 214217 | 499841 | 593180 |
| Cairo South (c.c.1) | 1*110+1*55 | 1995 | 1154 | 1 | 1154 | LFO/NG | 184.3 | 0 | 0 | 212682 | 175875 |
| Mahmoudia (c.c.) | 8*24.5+2*56 | 1993-95 | 1568 | 0.36 | 570 | LFO/NG | 207.9 | 0 | 0 | 118541 | 98026 |
| Damanhour(c.c.) | 4*24.2+1*56 | 1985-95 | 849 | 0.37 | 311 | LFO/NG | 193.2 | 0 | 0 | 60115 | 49711 |
| Esna | 6*15 | 1995 | 352 | 1 | 352 | Hydro | | 0 | 0 | 0 | 0 |
| Total | | | 7200 | | 5664 | | | | 214217 | 891179 | 916792 |
| Average emissions (C tons/GWh) | | | | | | | | | | | 161.85 |

^a. Assumptions were made due to non-availability of complete information. In case of Talkha, it was assumed that one unit of 210 MW was commissioned in 1995, and one before that. Similarly, 2*56 MW units were assumed commissioned in 1995 in the case of Mahmoudia and 1*56 in the case of Damanhour. For Walidia, one unit of 300 MW (commissioned after 1995).

^b. Generation was adjusted in proportion to the capacity commissioned in 1995 and afterwards.

Notes:

1. Ratio of HFO/NG use in 1996-97 (the year for which consumption data for HFO and NG was available) was 28.7:71.3. It was rounded off and assumed that HFO/NG use ratio in HFO/NG plants was 30:70 in 1999-2000. For 1999-2000, the data available only gives average fuel consumed g/KWh, not specifying it is NG or fuel oil. This being an average value, it was assumed same quantity of NG or fuel oil per unit of power produced (g/KWh) was used. Any variation from this ratio (30:70) may have implications for carbon emitted due to variation in calorific values of NG (54 TJ/ton) and fuel oil (40.19 TJ/ton).
2. LFO use was negligible in 1996-97. It was assumed that it was negligible in 1999-2000 also.

Table 28: Last five years of additions/top 20 percent in fuel category oil and gas fuels (HFO, LFO, NG and a mix of these fuels).^a

| Power station | No. Units | Comm. Date | Gross generation (GWh) | Fraction commissioned | | Fuel type | Fuel cons. rate (g/KWh) | HFO fraction | HFO used (tons) | NG used (tons) | Carbon emissions (tons) |
|---------------------------------|-------------|------------|------------------------|-----------------------|---------------------------|-----------|-------------------------|--------------|-----------------|----------------|-------------------------|
| | | | | 1995 and later | Adjusted generation (GWh) | | | | | | |
| Cairo west (ext.) | 2*330 | 1995 | 3277 | 1 | 3277 | HFO/NG | 217.9 | 0.3 | 214217 | 499841 | 593180 |
| Cairo South (c.c.1) | 1*110+1*55 | 1995 | 1154 | 1 | 1154 | LFO/NG | 184.3 | 0 | 0 | 212682 | 175875 |
| Mahmoudia (c.c.) | 8*24.5+2*56 | 1993-95 | 1,68 | 0.36 | 570 | LFO/NG | 207.9 | 0 | 0 | 118541 | 98026 |
| Damanhour(c.c.) | 4*24.2+1*56 | 1985-95 | 849 | 0.37 | 311 | LFO/NG | 193.2 | 0 | 0 | 60115 | 49711 |
| Total | | | 6848 | | 5312 | | | | 214217 | 891179 | 916792 |
| Average emissions (C tons /GWh) | | | | | | | | | | | 172.6 |

i.e. excluding renewables.

Table 29: Last five years of additions/top 20 percent in fuel category/specific fuel LFO/NG.

| Power station | No. Units | Comm. Date | Gross generation (GWh) | Fraction commissioned | | Fuel type | Fuel cons. Rate (g/KWh) | HFO fraction | HFO used (tons) | NG used (tons) | Carbon emissions (tons) |
|--------------------------------|-------------|------------|------------------------|-----------------------|---------------------------|-----------|-------------------------|--------------|-----------------|----------------|-------------------------|
| | | | | 1995 and later | Adjusted generation (GWh) | | | | | | |
| Cairo South (c.c.1) | 1*110+1*55 | 1995 | 1154 | 1 | 1154 | LFO/NG | 184.3 | 0 | 0 | 212682 | 175875 |
| Mahmoudia (c.c.) | 8*24.5+2*56 | 1993-95 | 1568 | 0.36 | 570 | LFO/NG | 207.9 | 0 | 0 | 118541 | 98026 |
| Damanhour(c.c.) | 4*24.2+1*56 | 1985-95 | 849 | 0.37 | 311 | LFO/NG | 193.2 | 0 | 0 | 60115 | 49711 |
| Total | | | 3571 | | 2035 | | | | 0 | 391338 | 323612 |
| Average emissions (C tons/GWh) | | | | | | | | | | | 159 |

Table 30: Last five years of additions/top 20 percent in fuel category/specific fuel HFO/NG.

| Power station | No. Units | Comm. Date | Gross generation (GWh) | Fraction commissioned | | Fuel type | Fuel cons. Rate (g/KWh) | HFO fraction | HFO used (tons) | NG used (tons) | Carbon emissions (tons) |
|---------------------------------|-----------|------------|------------------------|-----------------------|---------------------------|-----------|-------------------------|--------------|-----------------|----------------|-------------------------|
| | | | | 1995 and later | Adjusted generation (GWh) | | | | | | |
| Cairo west (ext.) | 2*330 | 1995 | 3277 | 1 | 3277 | HFO/NG | 217.9 | 0.3 | 214217 | 499841 | 593180 |
| Total | | | 3277 | | 3277 | | | | 214217 | 499841 | 593180 |
| Average emissions (C tons /GWh) | | | | | | | | | | | 181,01 |

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