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# Evaluation of the environmental impact of the 20 MW wind power project in Tejona, Costa Rica

## Report of Phase 2 of the Tejona Wind Power Project (TWPP)

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# Acknowledgement/Preface

This report was prepared on order of Essent Duurzaam B.V. of Essent Energie B.V.
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- Ing. Enrique Morales of the Instituto Costarricense de Electricidad (ICE), Tejona Wind Power Project Partner Representative
- Mr. Jan Willem van de Ven of Essent Duurzaam B.V., Tejona Wind Power Project Partner Representative
- Mr. Frans Van Hulle, who left ECN and concluded final drafting work on this report while working for his current employer, 3E Company in Belgium.
- General staff of Nordteco, Vestas and ICE for their assistance in collection of data.

## Background of reporting partners:

The **Energy research Centre of the Netherlands** (ECN) is a private organization for research, development, consultancy and knowledge transfer in energy and related fields. ECN develops and markets technologies and products for a safe, efficient and environmentally friendly energy supply. As part of a wide portfolio of work activities, ECN staff regularly carries out project appraisal, feasibility and environmental impact assessment studies under contract to governmental and private institutions.

**Arrakis** is private Dutch based consultancy active worldwide in renewable energy focused on project development and execution, and technology transfer. Arrakis staff has carried out appraisal work on feasibility studies for overseas wind farm developments and is highly active in wind energy capacity building in Europe, Asia, Latin America and Africa.

**Nordteco S.A.**, a private engineering and consultancy firm based in Costa Rica, is active with renewable energy projects of various types in Costa Rica and the geographic subregion. Nordteco S.A. played a key collaborative role on the preparation and execution of Tejona Wind Power Project in Costa Rica and has worked for several years with all primary Tejona Wind Power Project partners.

**Dr. Eugenia Flores Vindas** is officially recognized by the College of Biologists of Costa Rica as a professional Biologist under registration number 4-092-234 and is allowed to practise her profession in concordance with national law no. 4288. Dr. Flores is also authorized by the Ministry of Environment and Natural Resources of Costa Rica under resolution no. AJ-221-2003-SETENA to act as an environmental consultant under the professional classification of Biologist, registration number CI-065-96. She regularly carries out environmental assessment work for Secretaria Tecnica Nacional Ambiental, a department of the above-mentioned Ministry.

## Contents

# 1 Executive summary

This environmental impact assessment (EIA) study was executed within the framework of the 20 MW Tejona Wind Power Project (TWPP) of the Instituto Costarricense de Electricidad (ICE) in Costa Rica. The project is located on an extremely wind-resourceful site in the province of Guanacaste in the north of Costa Rica. This study was carried out for Essent Duurzaam B.V. by the Energy research Centre of the Netherlands (ECN), with assistance of specialist subcontractors in Costa Rica and Europe. The TWPP project is part of the Dutch government sponsored "Activities Implemented Jointly (AIJ)" initiated as a forerunner to future Netherlands "Clean Development Mechanism (CDM)" projects under the Kyoto Protocol.

The contents and scope of the study were defined in first instance following environmental impact assessment requirements applicable to Costa Rica. This report also incorporated criteria considered relevant to this project emanating from Dutch EIA requirements. The Tejona 20 MW project is already operational with environmental approval issued in 1993 for the ICE project, covering both existing installations and possible future extension plans. This EIA report provides an update, taking into account present project conditions, developments in the legal requirements, current methods and tools for environmental assessment and wind turbine technology actually used.

The report gives a detailed description of the Tejona 20 MW Wind Power Project and all relevant environmental characteristics[1]. Environmental impacts of the project are systematically analysed and summarized. Project benefits in terms of greenhouse gas abatement are described. Key aspects including land use, acoustic noise immissions, visual impact, safety, effects on soil and vegetation, influences birds and wildlife, and archaeological features are also assessed.

**The main conclusions from this report are that the project is beneficial in numerous aspects, while detrimental effects are negligible.** Highly effective generation of wind power on this site avoids emission of greenhouse gases as well as reducing the concomitant depletion of natural resources. This project also valorises land that is otherwise considered to have relatively low economic value and several other wind power projects have been operating in the same geographic area for a number of years. Using the available land on this remote site to deploy economic activities (with minimal negative impacts) is considered positively. The function of wind power generation is not in conflict with the existing planological destination of the area. Impacts on birds, vegetation, soil and other wildlife were considered either negligible or limited.

Because of its large size and because it is the first wind power project to be realized by the country's largest utility company, ICE, the demonstration value of this project is high. It is recommended that the Tejona project operators carry out detailed, professional monitoring to keep track of the operational performance and environmental impacts. Wind farm projects such as this one can play a crucial role in helping create a more reliable and sustainable national electricity supply in Costa Rica, both today and in the future.

[1] This report does not formally evaluate the environmental impact for any project extension plans. The present report however should provide a good basis for evaluation of such an extension. Annex 6 contains a simulation that shows the possible visual influences should an extension eventually be prepared.

# 2 Introduction

## 2.1 Background

The present study has been executed within the framework of the Tejona Wind Power Project (TWPP) – Costa Rica. The project falls under the “Activities Implemented Jointly (AIJ)” as a forerunner for the Netherlands “Clean Development Mechanism (CDM)” projects to reduce green house gas emissions under the Kyoto Protocol. This EIA report was commissioned by DGIS and was financed by the PPP-JI funds for the implementation of the 20 MW wind farm in Costa Rica. Essent Duurzaam Energie B.V. issued a subcontract to ECN to carry out the execution and related work activities. ECN collaborated with local experts in Costa Rica and other subcontractors as necessary. Essent Duurzaam B.V. and ICE staff provided information for further analysis.

Key objectives of the TWPP project are to transfer technology and skills expertise in wind energy to ICE, the Costa Rican electric power company. In order to determine the environmental aspects of the 20 MW wind power project, an environmental impact assessment was carried out as a sub-project (phase 2) of the TWPP project. The findings are presented in this report. The expected environmental impacts of the Tejona 20 MW wind project were originally evaluated and reported upon (ref. 1) in 1993. Those findings were mainly positive, with little environmental impact predicted, and an environmental permit was given to the project. Based upon the “ Informe Final ” [1], the Commission Interinstitutional de Evualacion y Control de Estudios de Impacto Ambiental (MIRENEM) approved the “Planta Eolica Tejona (ICE), including both the 20 MW Monte Cristo and the Altamira extension (10 August 1993).

The present report assesses the current situation following national regulations for environmental impact assessment in Costa Rica. Additional aspects of Dutch environmental impact assessment that were considered relevant for this type of project were also taken into account. In particular, the evaluation of the noise and visual impact of the wind farm were investigated using recently developed wind farm planning tools. The report contents list, as conceived by SETENA[2], was used a the basis for the reporting format.

## 2.2 Scope

The report investigates the environmental impacts of the Tejona wind power plant. The first part (20 MW) of this wind power plant has been implemented and put into operation at the time of the current EIA field works took place (September 2001 – October 2002). Thirty (30) Vestas V47 660 kW wind turbines were installed at the Montecristo ridge of the Tejona site. Annex 6 presents a hypothetical simulation of the possible visualization of a potential future 10MW extension.

[2] Secretaria Tecnica Nacional Ambiental (Department of Ministry of Environment and Natural Resources)

***Fig. 1*** *The complete 20  MW Tejona wind farm as seen from the SW side (distance 2 km).*

**Fig. 2.** *The 2* Wind energy already is integrated in the local environment in the form of a number of  large existing projects. *20 MW Tejona wind farm seen from the East side (distance 500 m)*

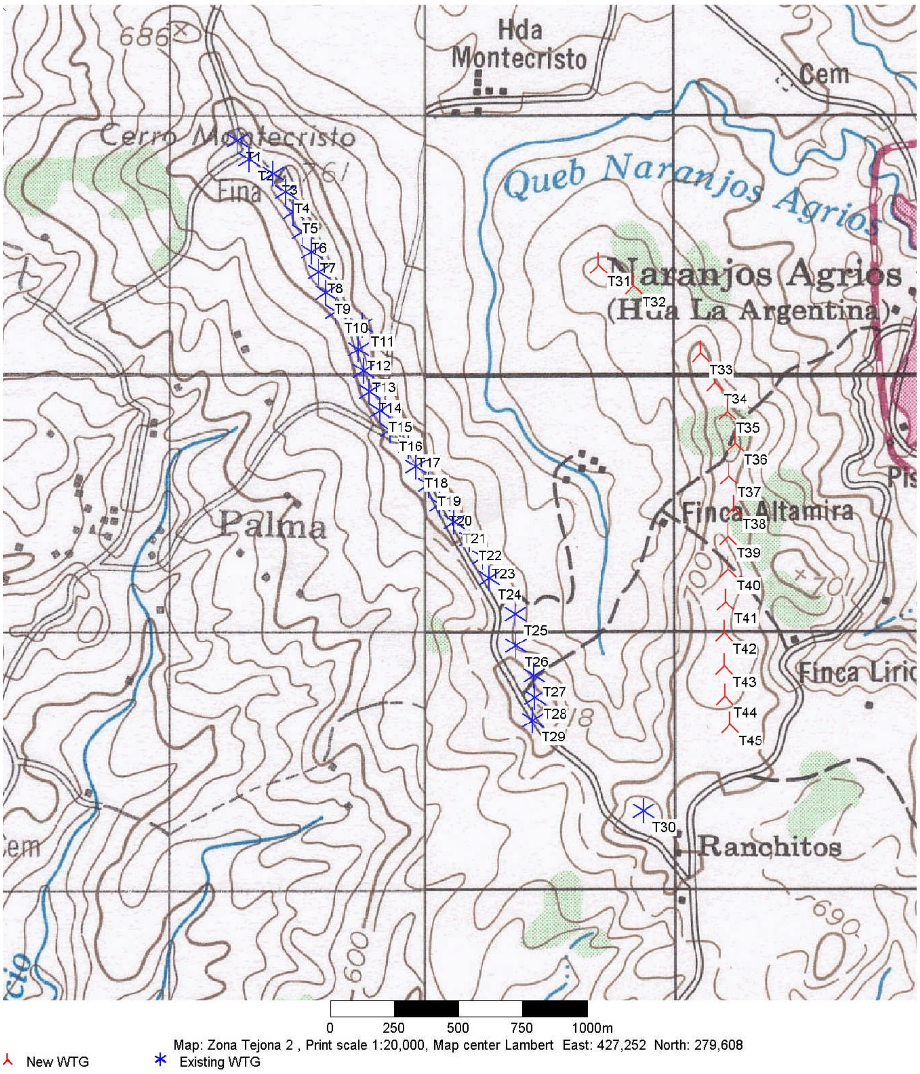


*Fig. 3. Situation of the existing 20 MW TWPP wind farm (blue crosses) and preliminary lay out of projected 10 MW extension (red crosses)*

# 3 General information

## 3.1 Details about the wind farm operator

The wind farm was built by a project team consisting of the Dutch electricity company Essent Energie B.V., the Danish wind turbine manufacturer Vestas A/S, and ICE. The 20 MW project consists of 3 parts and ICE is the main client. ICE purchases 5 MW of energy and leases 15 MW of energy from the project. Essent Energie B.V. provides all-inclusive operations and maintenance under a 5-year contract.

## 3.2 Terms of Reference of the Environmental Study

### 3.2.1 General

An Environmental Impact Study was already carried out in 1993 and the Environmental Permit was granted to this project [1]. The present environmental study has been executed on request of the Government of the Netherlands Directorate for International Cooperation (DGIS), under the framework of the donation to the Tejona Wind Power Project. The objective is to assess the effects of the wind power project on the environment, related to impacts such as noise, visual impact, safety, soil and vegetation, shadow effects, telecom, birds and other species and possible archaeological and historical values of the site. The present study has been carried out to fulfil the above requirements, reviewing the environmental impact under present conditions.

In accordance with the conditions of the PPP JI donation of DGIS, as described in [2], the terms of reference for the EIA have been defined - in agreement with ICE - taking into account requirements for current national practice in EIA reporting. It reflects local legislation in Costa Rica, the practice in the Netherlands, as well as international terms of reference for environmental impact assessment.

### 3.2.2 Legal Requirements for EIA in Costa Rica.

A number of laws are applicable for EIA in Costa Rica[3]. There are several sector laws, which contain specific articles on EIA [3], including the law on Generation of Electricity, which is applicable for wind power. The formal authority in charge of the EIA process is SETENA. The EIA procedures, responsibility and criteria in Costa Rica are also described in ref. [3]. The contents of the present Environmental Study are based upon those requirements, listed in detail in Table No. 20 of ref. [4].

### 3.2.3 Legislation of the Netherlands on EIA

EIA decrees by Dutch law have been published in Staatsblad, No 224, 1999. Article 1 states: “Wind energy (category 22.2) is environmentally friendly regarding fuel input, but wind turbines can have harmful effects on the environment, for example due to influence on migrating routes of birds, noise effects, safety aspects and influence on the landscape. In association with this, not only the total power plays a role, but also the number of wind turbines being installed. Therefore, a threshold of 10 turbines or 10 Megawatt is taken. The potential impacts on the environment concern in particular acoustic noise and visual hindrance, use of land, effects on soil, degradation of ecological values, external safety, water pollution and impacts on the landscape, culture and archaeology.” The Dutch requirements for the contents of EIA studies[4] are assessed on a case-by-case basis. Noise calculations and visualizations are always included in EIA reports in The Netherlands. For this reason, such elements are included in the present report.

### 3.2.4 International guidelines for EIA

The United Nations Framework Convention for Climate Change (UNFCCC), based in Bonn, Germany, refers EIA requirements to national legislation[5].

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3 EIA profile of Costa Rica, Internet website of the Commission for Environmental Impact Assessment, The Netherlands.

4 More detailed information on requirements for EIA studies can be found on the CDRom by NOVEM called ”Met de wind in de rug”.

5 Personal communication with Ad Dankers, UN consultant, May 2002.

### 3.2.5 Key Differences between original EIA and current EIA findings

In general, the current EIA covers actual specifications of the technology used and specific conditions encountered at the site of operations, whereas the original report only covered possible plans and available options because the project had not been implemented at the time of the original EIA investigations. Given that the project was completely operational at the time of the current EIA investigations, applicable SETENA requirements were addressed in order to cover current project status. Key differences are summarized below.

- ICE's Environmental Management Plan (Plan Gestión Ambiental) in the current report was described in detail following current SETENA guidelines.
- Technical specifications for selected wind turbines are known for the current EIA report. The original EIA report only specified the scope limited to the technology available in 1993 (namely 225kW or 400kW machines). Initial wind turbine spacing was suggested as 1.5 rotor diameters, however actual spacing was later defined as a minimum of 2 rotor diameters.
- Regular maintenance activities for the wind turbines, as well as operation procedures, are known and described in the current EIA based on actual equipment and suppliers.
- The current EIA report includes comments on the control building, and related infrastructure developed on the project site and surrounding vicinity.
- The environmental description inter alia remains basically the same as no major impact has been affected to the Tejona area. The former EIA predicted little impact on environment and current EIA report draws a similar conclusion.
- Acoustic noise, visual impact and visual influence zones were analysed with special software tools. The original EIA report only mentions possible effects of such aspects.

### 3.2.6 Conclusions

The present study discusses the following aspects:

- visual impact: visualisation of the appearance of the wind farm and determination of the zones of visual intrusion.
- influence on soil and vegetation during installation and operation;
- acoustic noise contour curves;
- electro-magnetic interference: possible effects on telecommunication;
- ornithological aspects: influence of wind farm construction and operation on migrating and breeding bird species in the environment.
- effects on wildlife during construction and operation;
- effects on archaeological and historical features in the area

The table of contents of the present report reflects the reporting format and aspects normally required for environmental studies of wind farms taking into account the considerations described in this paragraph.

# 4 Description of the Tejona 20 MW wind power project

## 4.1 Geographical situation

The 20 MW Tejona wind farm is located in the province of Guanacaste, in the Cantón of Tilarán. It is situated on the intersection of the 84°59’27” west latitude and 10°31’49” north latitude. The location on the topographical map is indicating in Fig. 3.

## 4.2 Political and administrative context

The project is administratively situated in the 4th district (Santa Rosa) of the Cantón Tilarán, Province Guanacaste, that is in the area designated as Pacífico Norte of Costa Rica.
There is a planning guideline for the Tilaran area named Plan Regulador de Tilarán, drafted by National Institute of Housing and Urbanism, Urban Direction (Instituto Nacional de Vivienda y Urbanismo, Dirección de Urbanismo, in Spanish). This plan is applicable for the mentioned area, which regulates the planological destinations of the Tilarán region [5].

## 4.3 Identification and description of the project

### 4.3.1 Brief history, parties involved

The project history dates back to the 1970's when ICE initiated wind measurements on the Tejona site and the government of Costa Rica applied to InterAmerican Development Bank and World Bank for debt financing for a wind power plant to be operated by ICE. A feasibility study was conducted in 1993 by Lynette and Associates, including a preliminary Environmental Impact Assessment. However it took until 1998 to find a project financing model – a BOL(T)[6] construction - which was acceptable for the Costa Rican Government. Following an International Tender process, issued by ICE in 1999, a consortium consisting of EDON NV and Vestas won the project. In this project group, the Energy research Centre of The Netherlands (ECN) acted as a Technical Consultant. Assistance was provided by the Costa Rican company Nordteco. The offer of EDON NV to ICE includes a donation from the Government of The Netherlands from the PPP-JI fund (Pilot Projects Programme Joint Implementation)[7].
The actual realization of the project includes the following:

- Direct supply of 5 MW (8 wind turbines), to be purchased by ICE;
- Supply of 15 MW (22 wind turbines) to be leased by ICE during a period of 5 years; after this period ICE can execute the right to purchase;
- A all-in operation and maintenance contract for five years for the 20 MW.

After the micrositing by ECN was finished (beginning of 2000), the site preparation started in July 2000. The installation of the wind turbines started in September 2000. By October 2000, 18 machines had been erected, and started operation in December 2001. Further construction of the wind turbines was suspended until May 2001 because of the high wind speeds, and safety restrictions of working only in wind speeds below 15 m/s. The works resumed in May 2002 and in June 2002 the last machines were installed, after which followed commissioning and normal operation of the plant.

[6] Build Operate Lease (Transfer)
[7] Edon NV project responsibilities were later taken over by Essent Energie B.V.

## 4.3.2 Technical description of the wind farm

### 4.3.2.1 General

The wind farm consists of 30 Vestas V47 machines of 660 kW, with a rotor diameter of 42 m, and a tower of 40 m.

**Wind farm lay out:**

| **Wind farm characteristics** | |
|---|---|
| total installed capacity | 20 MW |
| number of machines | 30 |
| position co-ordinates | see Annex 1 |
| main windfarm parts | 1 single row, with variable interdistance |
| altitude | between 685 and 755 m a.s.l. |

The wind farm lay out is depicted in Fig. 3

**Site description:** The site of Tejona with its hilly orography is characterised as complex terrain. The 20 MW wind farm is installed on the Montecristo ridge, which is perpendicular to the predominant wind direction (NE). The vegetation is primarily grass with a few patches of trees in the lower valleys between the Montecristo and Altamira ridges.

**Expected performance (report estimations)**

| | |
|---|---|
| Expected average annual energy production[8]: | 81 GWh |
| Expected equivalent full load hours: | 4050 h |
| Expected average net capacity factor: | 46 % |
| Expected annual GHG Emission Reduction[9]: | 40 000 tons of $CO_2$ |

## Basic criteria for wind farm lay out

The total amount of 20 MW has been installed on the Montecristo ridge. The minimal spacing between the wind turbines is 2 D (2 rotor diameters, 84 m) perpendicular to the prevailing wind direction (NE). The close spacing is chosen because it allows to minimize the infrastructure costs (roads, maintenance pads, cables), maximize the utilization of ground surface area for wind power extraction with the given wind turbine type, whilst maintaining low wind farm losses because of the constant wind direction perpendicular to the array line. The wind turbine line follows the crests of the ridge in order to maximize energy capture and minimize turbulence effects. Additionally, this configuration took into account that the Tejona site has sufficient space within its present property borders for future extension by approximately 10 MW.

## Lifetime

The expected technical lifetime of the wind farm is 20 years.

### 4.3.2.2 Foundations and civil works

The foundations for the 30 wind turbines consist of reinforced concrete blocks of 4,80 x 4,80 meters (hereafter "m") with a depth of 6m, buried into the ground. In addition to the wind turbine foundations, the civil work also includes installation of the foundations for the pad-mounted transformers. The transformer foundation surface dimensions are approximately

[8] Calculated by ECN based on detailed estimations of wind regime, and realistic assumptions on various losses. The assumptions are described in ref. 9.

[9] Project reference figure taken from the ICE Tejona Project Evaluation Report to DGIS dated June 2000.

2m by 1.5 m. Additional roads have been constructed for the installation and for the operation and maintenance. Access roads have been constructed per group of 2 wind turbines. A road has been developed along each ridgeline, approximately parallel to the row of wind turbines. Grading requirements for the project include access roads to the site, roads on the site, crane pads, foundation pads, and draining and culverts. Document ref [16] describes the technical characteristics of the wind turbine foundations and other civil structures on the site.

***Fig. 4*** *Wind power plant control building at Tejona, near wind turbine position #30.*

The roads on the site are approximately 3.5 m wide covered with a minimum of 100 cm of road base to allow traffic in rainy conditions. For the foundation pads, drainage will be sufficient to ensure that the foundation area remains free from standing water. In addition to the grading for foundation pads, the civil work will include grading of crane pads at each turbine location. These pads will be used for both construction and daily maintenance. The size of the crane pad conforms to the outrigger footprint of the 250 Tons crane used for the project (approximately 11 m by 15 m).

Finally, Fig. 4 shows the control building providing workspace for the operating engineers and technicians and storage room for spare parts, tools and auxiliary products. There is also dedicated space for meetings and technical training facilities.

### 4.3.2.3 Wind turbines

The wind turbine is the Vestas V47/660 kW modified for application on the special wind class site; the modification consists of a reduced rotor diameter (42 m instead of 47 m). The tower height is 40 m. Fig. 5 shows the wind turbine as installed in the Tejona project.

| **Main characteristics** | |
|---|---|
| rated power | 660 kW |
| rotor diameter | 42 m |
| hub height | 40 m |
| Rotational speed | nominal speed 28.5 rpm, variable between 0 and rated |
| aerodynamic control | Variable pitch |
| electrical | induction generator, variable speed (Vestas Optislip system) |

***Fig. 5** Vestas V47/660 kW in the TWPP wind farm (June 2002)*

Safety:

GL Wind certified the V47 wind turbine type according to Germanischer Lloyd Regulations. Additionally, GL Wind carried out a site-specific certification according to the site-specific wind and environmental conditions. The basic criterion is that the design of the wind turbine in the specific external conditions should ensure safe operation during the lifetime of 20 years. Because of the final adjustment to the site conditions, the rotor diameter was reduced from 47 to 42 m. The energy payback time of the wind turbines (time needed to generate the energy for manufacturing a turbine) in the local wind regime at Tejona is a couple of months of windy season.

#### 4.3.2.4 Grid connection

### *General*

Each wind turbine is connected via an underground 480 V line to a pad-mounted transformer where the voltage is increased to 34.5 kV. The 34.5 kV lines are then joined and run underground to a switchyard on the project site. The 34.5 kV transmission from the on-site switchyard to Arenal substation is by overhead lines.

A switchyard and the control building is located on the southern end of the ridgelines. Both of these facilities have been sized to permit incorporating future expansion, and the location of both the switchyard and the control building was chosen so as to be centrally located for any future expansion of the project.

### *High voltage cable*

The main high voltage magnitude for carrying out the electric power of the wind farm was designated as 34.5 kV. The main characteristics of the selected cable are: TRXLPE insulated URD for underground installation. The insulation level reaches 420 mils and is suitable for 35 kV applications. The core is solid with 4/0 aluminium material, surrounded by a copper spiral of 10x#14 cores acting as 1/3 neutral. Cables have a short circuit withstand with a lower limit of

10 kA. Total HV cable length is 19.2 km. The cables are directly buried in ground, sand backfilled, placed triangularly, with a 250 mm clearance between adjacent circuits and at the same depth, 1000 mm.
The cable rating is based on the following set of parameters:

- Cable design: as per GCC Dwg V-6652
- Cables installed direct buried in the ground
- Each circuit installed with three cables in a triangular touching configuration
- Circuits are spaced with 0.25 m intervening distance or 0.34m for circuit center-to-center spacing between the two triplexed cable bundles
- Cable depth of burial: 1 m to center of each triplexed cable bundle
- Earth thermal resistivity: 1.5°K m/w
- Earth ambient temperature: 30°C
- Conductor operating temperature: 90°C
- Circuit load factor: 100%
- Both circuits energized simultaneously at the same ampere load
- Wire shields solidly grounded at both ends of each circuit

### *Power collection system*

There are two circuits with 15 wind turbines each, connected in an open loop system. The first one: turbines #1 to #15 and the second one: turbines #16 to #30; therefore the circuit #1 has a junction box at turbine 16. The inlet terminals of the first transformer of each circuit are connecting  to the grounding system through the surge arrester (elbow connector) module, and the outlet terminals are connecting  to the next transformer through elbow connector modules. Each loop continues this way up to the fifteenth transformer, where the cables go directly to the substation. The high voltage connection accessories are: surge arrester elbow connector module, elbow connector module, cold shrink terminations, insert bushings and cold shrink splices.

### *Transformers*

There are 30 transformers of 750 kVA each, with at least the following characteristics:

- 34500 V grounded Y / 19920 V on primary side.
- 690 V grounded Y / 398V on secondary side.
- Primary insulation classes: 35 kV, 200 kV BIL and below.
- 60 Hz.
- 65ºC average winding rise.
- Voltage taps: ±2.5% and ±5%.
- Non-load full-range current limiting fuses on primary side.
- 2 positions T blade sectionalising loop switch on primary side.
- 6 hole NEMA spade terminals on secondary side.
- Impedance: 5.75%.
- Dead front-external clamped and removable HV bushings well for load break inserts.
- Nameplate per ANSI requirement.
- Draw out non-load break fuse canister with interlocking switch to load break switch.

The transformers do not have their own earthing system, however they are closer than 9 meters from the earthing system of the wind turbine, according to ICE earthing design.

## 4.3.3 Project phases

### 4.3.3.1 Construction phase

The wind farm was constructed in the period July 2000 – June 2002.
The construction phase included:

- Site preparation and excavations;
- Wind turbine foundations, transformer pads, wind turbine site pads and roads;

- Construction of control building;
- Wind turbine site assembly and erection;
- Electrical interconnection: cables, transformers, switchgear
- Commissioning tests.

A temporary camp was make  for construction workers, including offices and storage buildings.

## *Operation and maintenance phase*

### *General*

In this phase, commencing in December 2001, the wind farm will be in continuous automatic operation. In the first five years the operational responsibility of the wind farm will be Essent's responsibility. A team consisting of Vestas and ICE employees carries out the actual operation work.

### *Regular maintenance activities and operation issues*

The operation & maintenance tasks will be performed according to the regular Vestas plan. Service frequency is once every 6 months period; the first one was made during September 2002. The main activities involved in those duties were related to mechanical inspection, mechanical parts grease re-fills, overall cleaning, electrical tests and Vestas internal standards check procedures. For the planned O&M mechanical and electrical aspects, the necessary equipment, products and tools are stored in the control building. Only in exceptional cases, some items will have to be shipped in the future as well,  to ensure the normal operation of the wind farm.

The general maintenance activities include the following tasks:

- Every grease nipple needs to be checked  in order to avoid any grease leaking. Damaged nipples will be replaced. The check process needs to be executed very carefully and following a natural order, for example checking the front side of the nacelle and working towards the rear part, then the bottom where the nacelle gets connected working upwards to the tower.
- Each moving part of the turbine requires a respective grease type or oil. All the shafts, gears, bearings and similar component parts have to be filled  with a new grease layer or grease is pumped inside the bearings. All the quantities have been pre-established, so the process should be efficient.
- The entire wind turbine has to be clean during regular maintenance work execution . Every grease leak on the floor or inside the nose cone needs to be cleaned. Right after every new greasing job, the nearest sections have to be cleaned and free of any grease or oil spots. In this way highest labour safety levels will be maintained and the correct order of the current work place followed.
- Most of the electrical checking  procedures can be performed via the electronic control box, as described step by step in the Vestas internal procedures. All data collected during those tests are documented as well as the mechanical results.
- Finally, several routines are scheduled to test the turbine performance covering all the main components, from the blades to bolts to the tower foundation. For example, the gearbox oil must be sampled for analysis and detection of any possible failure.

All above items require the correct waste disposal, and this job was done during  the first O&M scheduled. Final waste treatment and disposal tasks are handled by the ICE utility operating under and subject to all locally applicable regulations.

### *General operation activities*

A control centre for a conventional power plant needs several staff to operate the generating machinery. This however is not the case of La Tejona Wind Farm, where the overall control of the wind farm is performed using software control. The entire energy production control, such as maximum power delivered to the net, can be pre-programmed for a day-by-day routine. This characteristic will reduce the needs for specialized staff or full time workers to execute the control of the wind farm.
The main aspects for the control of the wind farm can be divided into three main levels:

- Vestas control software;
- The computer operating the software;
- Specific staff in charge of the software maintenance and local support direct in site.

#### *Control software*

The control software is Vestas proprietary software based on SCADA technology, a very reliable and well-tested system control. The software presentation pursues clear and easy operation of the wind farm, without need for extensive computer skills. One of the most important characteristics of the control software is the ability to record every action performed on the complete wind farm; from random possible occurrences like grid interruption until scheduled maintenance tasks, as well as data related to energy production.
The software control acts as the core of the regular operation routine, because it is in charge of all the tasks related to keep the wind farms running, while no random events stops one or more turbines. In such situation, the local staffs takes charge of the situation and brings back the conditions enabling the automated software tools to keep the wind park up and running.

#### *Control Computer*

This is the physical medium where the algorithm contained in the control software can be converted into real orders to the wind turbines. This computer can be supported by communication media to achieve flawless operation of the control to the turbines, and for the data communication routines.  Some characteristics of the control physical media  depend on the local infrastructure.  Short Message System communication for example cannot be implemented in this project due to different technical capabilities of the communication net of Costa Rica.

#### *Local staff in charge of operation*

The operating personnel have direct control, anytime, over the general operation of the wind farm. All other resources to keep the power plant running were made to ensure the operation as a routine, but in the case of abnormal function or unexpected troubles, local staff will fix the problems or take the necessary measures to put things in order. The software capacity to establish two-way communication enables local staff to control the wind farm even in remote mode, enabling 24-hour and seven days a week availability by personnel in order to achieve optimum performance from the wind farm.

### 4.3.3.3 Decommissioning phase

The wind power plant will be decommissioned after 20 years. The decommissioning includes removal of the wind turbines and foundations. For the Tejona wind farm, there is not yet a decommissioning plan.

## 4.4 Regional regulatory framework

The legal and administrative framework is the local municipality of Tilarán. The specific regional regulatory framework is described in ref. 5, drafted in 1987 and still valid until now. Both for technical and environmental aspects, the national legislation of Costa Rica applies. The development of Renewable Energy in Costa Rica is regulated by a Law, which states the target

amount of renewable energy as a fraction of the national energy consumption. For wind energy the present target is 6 % of the electricity production, a quantity which actually has been reached.
Law 7152 passed on 1990 established the MINAE as the legal authority for natural resources. This law establishes the functions of the Ministry to formulate, plan, and implement natural resource and energy policy, and environmental protection. It also dictates that the Ministry assumes the functions of direction, control, financing, promotion and development of natural resources, energy and environmental protection. In order to do this, it must dictate, by executive order, obligatory norms and regulations related to the rational use and protection of natural resources and energy, as well as confer and process permissions and concessions related to its area of competence.

## 4.5 Estimated area of environmental impact

The environmental impact of the wind power project has two main components. On the one hand, the project will avoid $CO_2$ emissions and other polluting emissions of fossil fuel based power stations during 20 years of operation. The corresponding beneficial environmental impact is distributed over various parts of the country where power is generated. The local area of environmental impact (nature, air, soil, human) is restricted in a radius of approximately 5 km around the wind farm. For this area the impacts during construction and operation have been studied in more detail.

## 4.6 Developed infrastructure

The infrastructure developed for the project consists of local reinforcement of the electrical grid and the improvement of the local access roads to the wind farm. The modifications to the electrical grid are described in paragraph 0. The adaptations to the local roads were minimal. Essentially the road has been slightly widened, and the road covering has been improved – although not with asphalt – to allow access for regular O&M activities the whole year through.
Moreover a control building has been built, which will also be used as local information and demonstration centre for renewable energy. In this way the building can be considered as an infrastructure component for human capacity building.

## 4.7 Recurrent services needed during operation

### 4.7.1 Basic services

The basic necessities for the wind farm during the operational period include water, electric energy, grey and black water, and access roads. The required amounts do not exceed those of an average household combined with a small workshop. The services are concentrated in the control building. The occupation of the building will be on the average 2 people, during 8 hours a day.

### 4.7.2 Labour requirements

The labour requirements during the construction phase are described in Annex 3. The plant is continuously operated during the five first years by a team of two engineers. Major service is scheduled at six month intervals. The required amount of staff is low and is limited to a few engineers, technicians, and manual workers.

## 4.8 Disposal of waste

### 4.8.1 During construction phase

The disposal of waste during the construction phase was subject to the environmental plan of operations of ICE. The details are described in ref. [18]. The plan was set up such that the impacts on the environment during construction are controlled and kept as low as possible. The plan corresponds with the overall environmental policy of ICE, which is required to comply with national and local regulations.

### 4.8.2 During operation phase

The disposal of wastes during the operation phase is 1) subject to the environmental plan of operations of ICE and 2) determined by the amount of substances needed for the operation and servicing. The majority of the substances needed are for lubrication purposes (oils and greases). Furthermore there are substances needed for cleaning and painting. An overview of the substances needed as recommended by Vestas is given in Annex 2.

## 4.9 Concordance with the local physical / spatial planning

The physical planning in Tilarán is subject to a policy described in ref. [5] decreed in 1987. The document does not refer explicitly to wind energy. The document has not been updated since that time. There is therefore no “direct link” to the spatial plan regulations and this type of project. However, given that this project has already received its permit, and numerous permits have been issued for similar projects in this area (wind, large hydro, geothermal) resulting in a concentration of energy generation activities, it can be reasonably concluded that there is no interference with spatial planning.
In the framework of the donation of the Dutch Government, a training centre with a demonstration centre for renewable energy is being built. The objective is to train local technicians in renewable energy so that the employment possibilities of the local population will improve.

## 4.10 Financial description

The project cost is divided into two broad categories: works to be performed by ICE, and Equipment & Services Contract.

**PROJECT COST**

Million US$

| ITEM | MONTO | PERIODO |
|---|---|---|
| ICE Works | | |
| Civil Works, Erection, Administration | 5.07 | Lump sum |
| Main contract | | |
| Equipment Payment | 6.53 | Lump sum |
| Lease of Equipment | 0.64 | Quarterly during 5 years |
| O & M external | 0.11 | Quarterly during 5 years |
| O & M internal | 0.02 | Quarterly during 5 years |
| Purchase Option | 3.02 | Lump sum |

Rate of exchange, CRC ¢ / USD $: 315.21

The scope of the contract between ICE and Essent Energie B.V. is equipment supply (through lease and purchase) and O & M services. Both leasing and services are for a 5-year period. The cost is based on tender bidding prices. The balance of the project is included on ICE's Works.
The cost is calculated assuming the leasing final payment and a constant O&M through the economic life equal to the O&M bidding price. Project sunken cost, such as feasibility studies, land and right-of-the way, is not included. An economic evaluation is made calculating the net present value and the internal rate of return. The ICE minimum required IRR for conventional power projects is 12%. From the results it was concluded that the Tejona Project needs a subsidy of $4.1 million to meet these requirements. The IRR without subsidy is 9%.

**YEARLY CASH FLOW**

Million US$

| Year | Cost | | | | | | Benefit | Net Benefit |
|---|---|---|---|---|---|---|---|---|
| | ICE Works | Equipment Purchase | Equipment Lease | O&M | Purchase Option | Total Costs | | |
| 0 | 5.07 | 6.53 | | | | 11.60 | 0 | **-11.60** |
| 1 | | | 2.54 | 0.51 | | 3.05 | 2.10 | **-0.95** |
| 2 | | | 2.54 | 0.51 | | 3.05 | 1.68 | **-1.37** |
| 3 | | | 2.54 | 0.51 | | 3.05 | 1.94 | **-1.11** |
| 4 | | | 2.54 | 0.51 | | 3.05 | 3.23 | **0.17** |
| 5 | | | 2.54 | 0.51 | 3.02 | 6.07 | 2.55 | **-3.52** |
| 6 | | | | 0.51 | | 0.51 | 6.16 | **5.65** |
| 7 | | | | 0.51 | | 0.51 | 2.64 | **2.12** |
| 8 | | | | 0.51 | | 0.51 | 1.66 | **1.15** |
| 9 | | | | 0.51 | | 0.51 | 2.47 | **1.96** |
| 10 | | | | 0.51 | | 0.51 | 5.01 | **4.50** |
| 11 | | | | 0.51 | | 0.51 | 3.52 | **3.01** |
| 12 | | | | 0.51 | | 0.51 | 3.20 | **2.69** |
| 13 | | | | 0.51 | | 0.51 | 2.67 | **2.16** |
| 14 | | | | 0.51 | | 0.51 | 3.32 | **2.81** |
| 15 | | | | 0.51 | | 0.51 | 3.50 | **2.99** |
| 16 | | | | 0.51 | | 0.51 | 3.94 | **3.43** |
| 17 | | | | 0.51 | | 0.51 | 4.36 | **3.84** |
| 18 | | | | 0.51 | | 0.51 | 4.36 | **3.84** |
| 19 | | | | 0.51 | | 0.51 | 4.36 | **3.84** |
| 20 | | | | 0.51 | | 0.51 | 4.36 | **3.84** |
| Discount rate: | 12% | Net present value start of year 1: | | | | **26.30** | **22.15** | **-4.14** |
| **Internal rate of return** | | | | | | | | **8.8%** |

# 5. Site specific characteristics (pre-implementation)

## 5.1 General

In this section the site-specific environmental characteristics are described, such as they are valid before the project is implemented. The site characteristics include climatic conditions, geomorphologic characteristics, air, water, soil, and vegetation.

## 5.2 Climate

### 5.2.1 Temperature and humidity

The minimum temperature, which occurs in January, is 18.8 °C, the maximum temperature, which occurs in May, is 27.5°C. The annual average temperature is 23.1 °C. The annual relative humidity is 85 %, with a minimum of 80 % humidity during the whole year.

### 5.2.2 Precipitation

Two types of rainfall, which differ in duration and intensity, occur in the area. *La orografica* is characterized by continuous light rainfall over several days in contrast to *la convectiva*, which lasts only a few hours but is quite heavy. A more detailed description of the precipitation characteristics is given in the previous environmental study ref [1].

### 5.2.3 Wind

The wind regime at the site was studied in the framework of the micrositing of the TWPP project and described in report [9]. In the study, the site-specific wind regime has been derived by extrapolation from long-term measurements at station la Tejona (Lake Arenal) combined with data measured during a short period at the site. The characteristics valid for a height of 40 m above ground level are given in the table below. The representative frequency distribution is depicted in Fig. 6.

| **Parameter** | **Symbol** | **Value** | **Unit** |
|---|---|---|---|
| | | | |
| **Normal wind conditions** | | | |
| Weibull scale parameter | A | 15.5 | m/s |
| Weibull shape parameter | K | 2.69 | m/s |
| Mean wind speed | V | 13.6 | m/s |
| Mean ambient turbulence intensity | TI | 11 | % |
| Mean air density | • | 1.12 | kg/m |
| Exponential wind shear coefficient | • | 0.04 | - |
| | | | |
| **Extreme wind conditions** | | | |
| Maximum 10 min average wind speed | $WS_{10min}$ | 54 | m/s |
| Maximum 3 sec gust wind speed | $WS_{3sec}$ | ~69 | m/s |

The hurricane season occurs between June and November, with September and October being the heaviest months. There is a 6% probability of a hurricane directly affecting the country.

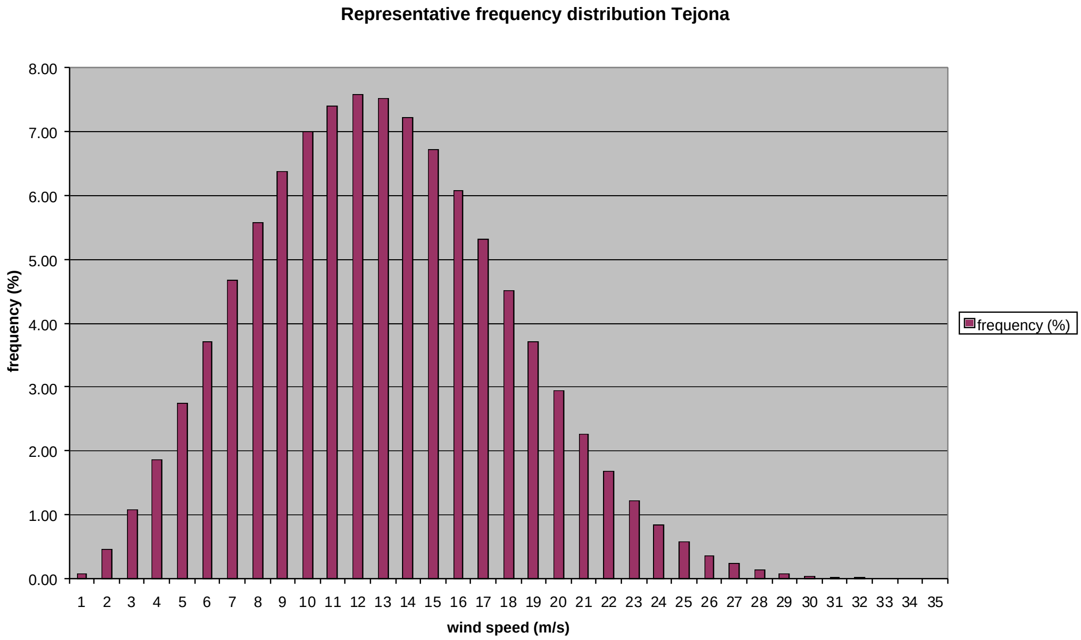


***Fig. 6*** *Frequency distribution determined from measurements and extrapolations by ECN [9].*

### 5.2.4 Evaporation

The annual evaporation is 1323.5 mm; the maximum monthly evaporation occurs in April and amounts to 159.3 mm [1].

### 5.2.5 Solar radiation

The maximum average daily amount of hours of sunshine occurs in March (7.8 hours) and the minimum in June (3.1 hours). The month of April has with 16 MJ/m$^2$ day the highest average amount of solar radiation.

### 5.2.6 Average Acidity

There are areas of volcanic activity found near the site that could have effects such as acid rain or significant acid soil. Samples of rain with an acidity (pH) between 4.7 and 4.9 have been taken (ref 1). These conditions could affect the installation by accelerating corrosion. As a result, corrosion protection measures will be required for wind turbine equipment. The impact of volcanic residue on electronic components will also be considered during equipment specification and will be incorporated into the maintenance program.

## 5.3 Geological and geotechnical characterisation

A geotechnical survey of the project site was conducted by ICE in March 1993. Six soil samples were taken in order to better define the soil characteristics of the project: four on the Montecristo Ridge and two on the Altamira ridge. Based on the observations at the site and on the laboratory results, it appears that the soil is basically homogenous and is unlikely to exhibit significant erosion or drainage problems. ICE has extensive experience with construction in similar soil conditions due to the construction of the Arenal hydroelectric facilities.
In general, the geotechnical analysis did not indicate any potential problems for development of the site for a wind project. It is standard procedure for ICE to conduct a more detailed geotechnical analysis before starting a project.

ICE conducted a geo-electrical survey in 2000 to determine the constitution of various layers by means of measuring the electric conductivity. This is reported in [13]. A report of perforations at various sites, with the description and capacities of the ground layers up to a depth of 15 m is included in the feasibility study [14].

### 5.3.1 Geomorphology

The geomorphology was briefly described in the previous Environmental Study [1]. It was concluded that the region is not subjected to delamination and that the orography is relatively stable. As a consequence the excavation work for the civil constructions would be relatively easy, which actually was the case.

## 5.4 Characterisation of the soil

As described in the previous Environmental Study [1], the soil is from volcanic origin. There are observations neither of substantial erosion nor of drainage problems.

## 5.5 Land use

The land use designations are classified as being rural, rural residential, and scenic for the affected areas. The affected areas cover sparsely populated zones near the project site and the transmission line corridor. Residential patterns in the vicinity are composed primarily of dispersed houses in rural settings. Because of the high winds, residences tend to be located in the valleys between the ridgelines and the surrounding land is used for grazing. It is expected, therefore, that few inhabitants would be exposed to the project and potential impacts would be negligible.

The land is primarily used for raising dairy cattle (1 head/hectare) and some milk processing. Approximately 95% of the land is pasture with some trees. There is some farming on a small scale, but this activity is very limited due to the strong winds.

The general condition of the roads and infrastructure is good in the project area: 34.8% of the roads in the area are paved, 65.2% are of ballast or gravel. Approximately 700 to 750 vehicles travel daily between Tilarán and Cañas. The only road considered in bad repair is between the village of Los Angeles and the project site.

## 5.6 Air quality

### 5.6.1 Atmospheric contents

The atmospheric contents are influenced by the proximity of the volcano. The acidity and other contents must be taken into account in the specification of the corrosion protection for the wind turbines.

### 5.6.2 Background noise

The natural background noise level in the environment is low. There is no industrial activity, and roads are quite distant. The noise level in the immediate neighbourhood of the site is somewhat influenced by the presence of one 20 MW wind farm (Plantas Eolicas Tejona), consisting of 60 Kenetech 33m/VS machines of 33 m diameter.

## 5.7 Natural threats

### 5.7.1 General

The foremost important natural threat is posed by the presence of tectonic instability. The region is earthquake-prone. Extensive studies have been done also in view of the construction of the hydropower installations.

### 5.7.2 Seismic threats

The seismic threats are reported in the previous Environmental study [1]. Based on the 1989 report, "Consideraciones Neotectonicas Recientes en los Alrededores de la Laguna de Arenal" by Geologist Guillermo E. Alvarado, Department of Geology at ICE,there are several known active and potentially active faults in the area surrounding the Lake Arenal.

After the eruption of the Arenal volcano in 1968 and a major earthquake at Tilarán a year later, ICE installed a complete seismological network to monitor all potentially active faults. Several geological photographs and field studies indicate the existence of the following faults, but none of these has been evaluated with neo-tectonics criteria.

- Cote Arenal Fault: This semicurve linear fault runs NW-SE to WNW-SSE. It extends more than 30 km from the Arenal volcano in the east to Cote-Laguna in the west. This is considered to be the most active fault in the area and could create seismic activity that could have a displacement of 10 cm per event. In the last 3,000 years, there have been 54 events of importance for an average of one every 55.5 years.
- Del Castillo Fault: There is limited information available on this fault, which is very close to the population center of Castillo.
- Dauta Fault: This fault runs north-south with a minimum length of 6 km, and affects Lake Arenal by a vertical displacement of at least 1.2 in. This fault movement is about 0.6 mm per year.
- Chiripa Fault: This fault is associated with Tilarán earthquake of April 14, 1973 (Richter scale: 6.5). Field and air photographs indicate a discontinuous alignment and the fault line extends to the Laguna Cote, joining the Cote faults.

Experience with wind power projects in other seismic active areas in the world indicates that this aspect would not deter project development in the Tejona area. Moreover the design of the wind turbine foundations in Tejona took into account a safety factor for earthquake-induced loads. The manufacturer also checked the wind turbine design for earthquake loads. Finally it should be noted that ICE has significant experience with construction and design in earthquake prone areas.

### 5.7.3 Volcanic threats

The site is situated in the middle of a region with major volcanoes. However, in view of the low activity level of the volcanoes and their geographical distance to the site, the immediate threat of the volcanoes is considered to be very limited.

***Fig. 7*** *The volcano Arenal, approximately 30 km NE from the projects site.*

### 5.7.4 Erosion

As the area is almost totally covered with grass, airborne erosion is quite limited despite the very high wind speed. Erosion of the roads by rainfall is a problem in some seasons. In the immediate surroundings of the wind farm, the roads have been paved, such that erosion risk is diminished.

### 5.7.5 Other

No other significant natural threats are occurring beside the listed ones.

### 5.7.6 Map of susceptibility (risk)

The natural risk at the site is limited to the risk of earthquakes. The susceptible area (mapped by ICE) extends in a radius of approximately 30 km around the site.

## 5.8 Vegetation

### 5.8.1 General

The Instituto Nacional de Biodiversidad (INBio) prepared a list of all species of flora believed to be in the area. The list categorizes the species based on the elevation at which they can be found and identifies various levels of potential endangerment. The site is classified as a semi-deciduous, low, tropical forest. There are several species of plants and none are considered to be in danger of extinction. The following text in paragraph 5.8 is taken integrally from report [23] by Dr. Eugenia Flores.

### 5.8.2 Species

The project is located in the Tropical Moist Forest life zone (bh-T), in transition to premontane (bh-T•). Temperature average range is 21.5 – 24 °C[10]. Dry season is variable (0 – 5 months). In the past, natural vegetation was formed by dense forests with a forest canopy 30-40 m height, intermediate between dry forests and a very humid tropical forest. Vegetation was evergreen, although some species were partially caducifolious. Epiphytes were abundant.

[10] The environmental impact study made by ICE in 1993 reports a different temperature range (18.8 – 27.5 $^{0}$C). The data correspond to Nueva Tronadora Meteorological Station (years 1979-1991).

## 5.8.3 Flora

| **Species** | **Family** | Common name | **Observations** |
|---|---|---|---|
| *Albizia* sp. | Fabaceae- | Cenízaro macho, gavilán | Tree, woody. Scarce in pastures or close to fences. Not in DIA. |
| *Andropogon bicornis* | Poaceae | Cola de venado | Introduced grass. African origin. Herbaceous. |
| *Aphelandra* sp. | Acanthaceae | | Herb, open places. |
| *Begonia* sp. | Begoniaceae | Begonia | Herb. In humid places, under shade. |
| *Asclepias curassavica* | Asclepiadaceae | Viborana, mata caballo. | Herb. In pastures, and trial edges. Toxic. |
| *Bidens pilosa* | Asteraceae | Moriseco | Herb. Open places. |
| *Bombacopsis quinatum* | Bombacaceae | Pochote | Tree, woody. Mainly used in fences. |
| *Bursera simaruba* | Burseraceae | Jiñocuave, indio desnudo | Mainly used in fences. Arboreal, woody. |
| *Bursera sp.* | Burseraceae | Jiñocuave, indio desnudo | Mainly used in fences. Arboreal, woody. |
| *Byrsonima crassifolia* | Malpighiaceae | Nance. Candle berry, locus berry. | Small tree. Woody. Edible fruit. |
| *Croton niveus* | Euphorbiaceae | Croton, colpachi | Shrub. Fences. |
| *Cynodon nlemfuensis* | Poaceae | Estrella, estrella africana. African star | Introduced grass. African origin. |
| *Desmodium* sp. | Fabaceae-Papilionoideae | | Weed. Open places. |
| *Enterolobium cyclocarpum* | Fabaceae-Mimosoideae | Guanacaste. Earpod. | Tall tree, woody. Shade for cattle. Not seen in the DIA. |
| *Ficus* spp. | Moraceae | Higuerón. Fig tree. | Trees, woody. In pastures or fences. |
| *Gliricidia sepium* | Fabaceae-Papilionoideae | Madero negro. | Mainly used in fences. Small tree, woody. |
| *Hyparrhenia rufa* | Poaceae | Jaragua, puntero | Introduced grass. African origin. Herbaceous. |
| *Inga* spp. | Fabaceae-Mimosoideae | Guabas. Guava. | Shrub or tree. Some tree in pastures. |
| *Lantana camara* | Verbenaceae | Cinco negritos. | Herb. Indicator of disturbance. |
| *Lonchocarpus* spp. | Fabaceae-Papilionoideae | Chaperno. Bitterwood. | Tree, woody. Scarce trees in pastures or close to fences. |
| *Mimosa pudica* | Fabaceae-Mimosoideae | Dormilona. | Weed, herbaceous. Typical in open places |
| *Psidium guajava* | Myrtaceae | Guayaba. Wild guava. | Small tree, common in pastures. Edible fruit. |
| *Psidium guineense* | Myrtaceae | Güísaro, guayabo de sabana | Common shrub. Edible fruit. |
| *Sida rhombifolia* | Malvaceae | Escobilla | Weed. Open places, trail edges. Native |
| *Spondias purpurea* | Anacardiaceae | Jocote. Spanish plum. | Tree. Seen in fences. Woody, edible fruit. |
| *Urera* sp. | Urticaceae | Ortiga | Sporadic. |

Endemic, endangered or threatened species[11]. None observed.

[11] Decreto Ejecutivo N° 25700-MINAE (La Gaceta N° 11, 1997).

## 5.9 Fauna

### 5.9.1 General

There is a low diversity of fauna[12] in this region because of the alteration of the forest to give right of way to dairy cattle. From destruction of habitats, the majority of mammals have been displaced to other areas, where they have permanently adapted. Existing mammals in the vicinity include rabbits, horses, rats, squirrels, and cattle, none of which are in danger of extinction. The following text is taken integrally from report [23] by Dr. Eugenia Flores.

### 5.9.2 Amphibians

Most amphibians[13,14,15] live in the forest. They are scarce in the Tejona area. At regional level (Central America) many species are disappearing as consequence of acid rain, soil, water, and air pollution, as well as agrochemical residues. *Hyla* species, reported in 1993[16], are arboreal, do not tolerate disturbance and are almost extinct. Pastures cover the area and trees are scarce. Knowing the story of disturbance characterizing the area, probably the species had not been in the area since the massive logging giving rise to the vast deforestation observed.

| **Nº** | Species | Common name | Classification | Observations. |
|---|---|---|---|---|
| 1 | *Eleutherodactylus* sp. | Tropical Frog | Anura/Leptodactylidae | Reduced populations. Not seen. Probable in IIA |
| 2 | *Bufo marinus* | True toad, giant toad | Anura/ Bufonidae | Common. |
| 3 | *Rana warschewitschii* | True Frog | Anura/Ranidae | Not seen. Probable. |

Endemic, endangered or threatened species Eleutherodactylus species have reduced populations.

### 5.9.3 Reptiles

The group of reptiles[17,18,19] is uncommon in the area. Observations realized in several areas have shown that some snake populations are increased when disturbance takes place.

| **Nº** | **Species** | **Common name** | **Classification** | **Observations** |
|---|---|---|---|---|
| 1 | *Rhinoclemmys* sp. | Brown land turtle (Tortuga de tierra) | Testudinata/Kinosternidae | Terrestrial. |
| 2 | *Boa constrictor* | Boa constrictor (Boa o bequer ) | Serpentes/Boideae | Scarce. Semi arboreal. |
| 3 | *Clelia clelia* | Zopilota (Mica) | Serpentes/Colubridae | Scarce. Terrestrial. |
| 4 | *Imantodes cenchoa* | Chunk-headed snake (Bejuquilla) | Serpentes/Colubridae | Common. Arboreal. |
| 5 | *Drymobius margaritiferus* | Sabanera | Serpentes/Colubridae | Common. Terrestrial. |
| 6 | *Crotalus durissus* | Tropical rettlesnake (Cascabel) | Serpentes/Viperidae | Frequent. Terrestrial. |

Endemic, endangered or threatened species. Boa constrictor has a reduced population.

### 5.9.4 Birds

The list of birds[20,21] is not exhaustive and other species may visit the area[22,23,24].

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[12] Wild fauna is protected by Ley de Conservación de Vida Silvestre No 7317, 1992 (Wildlife Conservation Law No 7317).

[13] Decree No 26.435-MINAE

[14] Savage, J.M. & Villa, J. 1986 Introduction to the herpetofauna of Costa Rica. Contributions to Herpetology No 3. Miami, Fla: University of Miami.

[15] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

[16] ICE 1993 Estudio de Impacto Ambiental de la Planta Eólica Tejona.

[17] Decree No 26.435-MINAE.

[18] Savage, J.M. & Villa, J. 1986 Introduction to the herpetofauna of Costa Rica. Contributions to Herpetology No 3. Miami, Fla: University of Miami.

[19] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

| Nº | Species | Common name | Classification | Observations |
|---|---|---|---|---|
| 1 | *Bubulcus ibisiatus* | Cattle egret (Garcilla bueyera, garza del ganado) | Ciconiiformes/Ardeidae | Eats mostly grasshoppers and other insects flushed by grazing livestock. Common. |
| 2 | *Cathartes aura* | Turkey vulture (Zonchiche, noneca, zopilote cabecirrojo) | Falconiformes/Cathartidae | Abundant. Common resident countrywide. Quarters back and forth at low to medium heights. Migratory. |
| 3 | *Coragyps atratus* | Black vulture (Zoncho, gallinazo, zopilote negro) | Falconiformes/Cathartidae | Abundant. Common resident countrywide. Part of the population may be migratory. |
| 4 | *Buteo brachyurus* | Short-tailed hawk (Gavilán colicorto) | Falconiformes/Accipitridae | Habitat: forest and open places. |
| 5 | *Elanus caeruleus* | Black-shouldered kite (Gavilán bailarín, elanio coliblanco) | Falconiformes/Accipitridae | Common. Habitat. Open places and pastures. |
| 6 | *Colinus* sp. | Bobwhite (Codorniz) | Galliformes/Phasianidae | Habitat: scrubby savanna, open places. Resident. |
| 7 | *Columbina passerina* | Common ground-dove (Tortolita) | Columbiformes/Columbidae | Habitat: open areas, pastures. |
| 8 | *Aratinga finschi* | Crimson-fronted parakeet (Catano, cotorra, perico frentirrojo) | Psittaciformes/Psittacidae | Habitat: forest edges, plantations, secondary growth. Permanent. |
| 9 | *Aratinga nana* | Olive-throated parakeet (Perico azteco) | Psittaciformes/Psittacidae | Habitat: forest edges, plantations, secondary growth. Permanent. |
| 10 | *Piaya cayana* | Squirrel cuco (Bobo chizo, cuco ardilla) | Cuculiformes/Cuculidae | Habitat: forest, plantations, open places. Probable. |
| 11 | *Tyto alba* | Common barn-owl Lechuza ratonera, lechuza de campanario, cara de gato, búho. | Strigiformes/Tytonidae | Habitat: open places, secondary growth. Permanent. |
| 12 | *Ciccaba virgata* | Mottled owl (Guía del león) | Strigiformes/Strigidae | Uncommon, but probable. Habitat: open places. |
| 13 | *Nyctidromus albicollis* | Common pauraque (Cuyeo, pucuyo) | Caprimulgiformes/Caprimulgidae | Common. Habitat: forest edges and open places. Probable. |
| 14 | *Chaetura vauxi* | Swift (Vencejo común o grisáceo) | Apodiformes/Apodidae | Común. Habitat: flies over the territory. Probable visitor. |
| 15 | *Amazilia tzacatl* | Rofoustailed hummingbird (Colibrí) | Apodiformes/Trochilidae | Abundant. Habitat: open places, secondary vegetation. |
| 16 | *Myiodynastes luteiventris* | Sulphur-bellied fllycatcher (Mosquero listado) | Passeriformes/Tyrannidae | Habitat: forest edges, secondary growth, open places. Migratory. |
| 17 | *Myiozetetes similis* | Social flycatcher (Mosquero ceja blanca, pecho amarillo) | Passeriformes/Tyrannidae | Common. Habitat: secondary growth, open places Resident. |

[20] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).
[21] Decree No 26.435-MINAE.

[22] Stiles, G. S. & A. F. Skutch 1989 A guide to the birds of Costa Rica. Ithaca, New York: Comstock Publishing Associates.

[23] Lewis, T. J. & G. S. Stiles 1980 Locational checklist of the birds of Costa Rica. San José, Costa Rica: Costa Rica Expeditions (Mimeo for bird watchers).

[24] Decree No 26.435-MINAE.

| | | | | |
|---|---|---|---|---|
| 18 | *Hirundo rustica* | Barn swallow (Golondrina tijereta) | Passeriformes/Hirundinidae | Common. Habitat: flies over the territory. Migratory. |
| 19 | *Campylorhynchus rufinucha* | Rufousnaped wren (Chico piojo, salta piñuela, soterré nuquirrufo) | Passeriformes/Troglodytidae | Frequent Habitat: generalist. Resident |
| 20 | *Thraupis episcopus* | Blue-gray tanager (Viudita, tangara azuleja) | Passeriformes/Thraupidae | Common. Habitat: forest edges, secondary growth, open places. Resident. |

In other projects, birds returned to the site when restoration ends and the Project start the operation phase. Sporadically, a bird could be killed by the windmill wings.
*Endemic, endangered or threatened species. None observed.*
There are several migratory species crossing the zone; however, they fly at high altitude and descend on forest patches. They were excluded for this reason.

### 5.9.5 Mammals

In Costa Rica, most mammals[25,26,27,28,29] are endangered, threatened or have reduced populations. Furtive hunting is forbidden by law.
The following species occur in Costa Rica: (popular name) Zorro pelon, Zorrici, Vampiro comun, Mono Congo (endangered species, see pictures), Armadillo Zopilote (rare, seen at the site), Oso hormiguero, Conejo de monte, Ardilla enana, Coyote and Pizote. The following mammals, belonging to the family of cats are uncommon (rare) and/or endangered: Olingo, Puma, Jaguar, Ocelot and Leon Breñero. A more extensive list of occuring species is given below.

| **Classification and scientific name** | **Common name** | **Observations** |
|---|---|---|
| Didelphimorpha | | |
| Didelphidae | | |
| *Didelphis virginiana* | Virginia opossum (Zorro pelón o zorro pecho amarillo) | Common. Nocturnal and terrestrial. Habitat: forest, plantations, and urban areas. Diet: fruits and small vertebrates. |
| *Marmosa mexicana* | Mexican mouseopossum (Zorricí) | Common. Habitat: forest, savannas and plantations. Diet: fruits and small vertebrates. |
| | | |
| Chiroptera | | |
| Phyllostomidae | | |
| *Desmodus rotundus* | Common vampire bat (Vampiro común) | Habitat: pastures, associated to livestock, plantations and forest. This species may carry rabies. |
| | | |
| Primates[30] | | |

[25] Carrillo, E., Wong, G. & Sáenz, J.C. 1999 Mamíferos de Costa Rica. Heredia, Costa Rica: INBIO.
26 Decree No 26.435-MINAE.
27 Mora, J. M. 2000 Los mamíferos silvestres de Costa Rica. San José, Costa Rica: EUNED.
[28] Sáenz, J., Carrillo, E., Wong, G. 1999 Mamíferos del Área de Conservación Arenal. Heredia, Costa Rica, INBIO.
[29] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).
[30] No included in the list: *Cebus capucinus* (mono carablanca, white-faced monkey) because it is found in undisturbed places. *Ateles geoffroyi* (mono Colorado, mono arena, spider monkey is restricted to primary or mature secondary forests. These species are present in Monteverde, Tenorio (ABIPA), Arenal (Tucanes trail, Cerro Chato), Santa Elena Manuel Alberto Brenes reserves.

| | | |
|---|---|---|
| Cebidae | | These monkeys always make noise and can be detected before meeting them. |
| *Alouatta palliata* | Howler monkey<br><br>(Mono congo, mono aullador) | Habitat: Found in available places (typically primary and secondary forest, riparian forests or forest edges) from sea level to 2.500 m.a.s.l. Diurnal and arboreal. Diet: leaves, flowers, and immature fruits. It has a small home range. Status: endangered (Decree No 26.435-MINAE, CITES, Appendix I). Seen in the site. |
| | | |
| Xenarthra | | |
| Dasypodidae | | |
| *Cabassous centralis* | Central American five-toed armadillo<br><br>(Armadillo zopilote) | From sea level to 1800 m. Habitat: humid and dry forests and savannas. Nocturnal, fossorial and solitary. Flees when it senses danger. For shelter, it digs holes in rocks or in the ground. Diet: termites, ants, and other invertebrates.<br><br>Status: rare, reduced population. (Decree No 26.435-MINAE, CITES, Appendix III). Seen in the site. |
| Myrmecophagidae | | |
| *Tamandua mexicana* | Northern tamandua<br><br>(Oso hormiguero, oso mielero, oso chaleco, tamandúa.) | Habitat: forests and savannas with trees. Diurnal and nocturnal, solitary, arboreal and terrestrial Diet: ants, termites, bees Probable. |
| | | |
| Logomorpha | | |
| Leporidae | | |
| *Sylvilagus brasiliensis* | Forrest rabbit<br><br>(Conejo de monte.) | Frequent. Habitat: open areas or early secondary growth. Nocturnal. Diet: young leaves and stems. It is attracted to salt, including that in human urine. |
| | | |
| Rodentia | | |
| Muridae | | |
| *Sigmodon hispidus* | Hispid cotton rat<br><br>(Ardilla enana.) | Common. Habitat: early secondary growth, pastures and plantations. Diurnal and terrestrial. Diet: seeds, herbs, young leaves, young birds, tubers, insects, lizards, fungi, eggs. |
| | | |
| Carnivora | | |
| Canidae | | |
| *Canis latrans* | Coyote (Coyote.) | Common. Nocturnal (sometimes diurnal). Habitat: savannas with trees, forest edges. Diet: rodents, rabbits, birds, reptiles, fruits, seeds, carrion, turtle eggs, and arthropods.<br><br>The population is growing. The species benefits from environmental disturbance. |
| | | |
| Procyonidae | | |

| | | |
|---|---|---|
| *Nasua narica* | Coati<br>(Pizote.) | Common. Diurnal; lives in social groups. Habitat: forest, pastures and plantations. Omnivore. Regular visitor to camping areas. |
| *Bassaricyon gabbii* | Olingo, cacomistle | Rare. Nocturnal and arboreal. Habitat: forests but it tolerates disturbed environments. Sleeps in hollow trees. It barks loudly Status: endangered (Decree No 26.435-MINAE, CITES, Appendix III). Diet: fruits (*Cecropia*, *Inga*, *Ochroma*), invertebrates and rodents. |
| | | |
| Felidae[31] | | |
| *Puma concolor*<br>(= *Felis concolor*) | Puma, mountain lion<br>(Puma o león de montaña) | Rare. From sea level to 3300 m. Habitat: dry, cloud and, gallery forests. Adaptable to open places. Solitary, terrestrial, active night and day. Diet: birds, small mammals, monkeys, iguanas. Status: endangered (Decree No 26.435-MINAE, CITES, Appendix I). |
| *Panthera onca* | Jaguar, tigre | Uncommon. From sea level to 3800 m. Solitary, active day and night. Habitat: a wide range of environments. Diet: carnivore; due to loss of habitat in the ACA, the jaguar has become a predator of domestic cattle. Status: endangered (Decree No 26.435-MINAE, CITES, Appendix I). |
| *Leopardus pardalis*<br>(= *Felis pardalis*) | Ocelot<br>(Ocelote, manigordo) | Uncommon. From sea level to 3800 m. Solitary, terrestrial, nocturnal and crepuscular (dusk). Habitat: forests, plantations, adaptable to disturbed habitats. Diet: carnivore; The ocelot is a predator of domestic poultry and pigs. Status: endangered (Decree No 26.435-MINAE, CITES, Appendix I). |
| *Herpailurus yagouaroundi*)<br>*(= Felis yagouaroundi)* | Jaguarondi<br>(León breñero, yaguarundi) | Uncommon. From sea level to 2000 m. Diurnal, terrestrial and solitary. Habitat: forests, plantations; among felines, it is the best adapted to disturbed habitats. Seen crossing roads. It uses a wide range territory (20 – 100 $km^2$). Status: endangered (Decree No 26.435-MINAE, CITES, Appendix I). |

### 5.9.6 Domesticated fauna

*Bos taurus* (cattle).
Equus caballus (caballo).
Endemic, endangered or threatened species. As indicated in the table.

## 5.10 Archaeology

No cultural remains were found during an exploration made by Museo Nacional de Costa Rica. In comparing the project site with existing data, the only area where archeological remains might be present is near the hill to the east of the Montecristo ridge. The authors of the

[31] These cats have been observed (mainly at night) on trails in Tenorio (Cote and ABIPA), Arenal (shores of Lake Arenal, Cerro Chato and highlands), Monteverde and santa Elena Reserves.

feasibility study [13] recommended verifying cultural remains in the area of the site on occasion of the excavation. This has been done in January 2002 by an investigating team of ICE. The findings have been reported in [12].

## 5.11 Baseline socio-economic conditions

The project site is located in the districts of Tilarán and Santa Rosa. Tilarán has an area of 138.78 $km^2$ with a population of 5,926 and a density of 43 people/$km^2$. Santa Rosa has an area of 71.11 $km^2$ with a population of 1,309 and a density of 18 people/$km^2$.

Costa Rica uses a grading system of social development taking into account eight factors related to health, education, and lifestyle. The Index of Social Development (ISD) assigns a value based on the previous factors on a scale of 1.00 (best situation) to 10.00 (worst situation). The province of Guanacaste presents the least favorable situation with a score of 6.49. The national average is 5.49. The canton of Tilarán has been given a rating of 4.25, a level of high social development.

## 5.12 Existing windfarms

Before the installation of the present project, three other wind power projects were installed and are in operation in the vicinity. The closest project located on an adjacent site is the 20 MW project operated by Plantas Eolicas Tejona, with 60 machines Kenetech VS 33, diameter 33 m. Another project is located a few kilometers away called the Aeroenergia 6.0 MW project with 8 machines NEG Micon 1500. The third project in the region is the Tierras Morenas project consisting of 27 NEG Micon machines with total installed capacity of 24 MW. The existing wind farms in the immediate vicinity are a dominating element in the landscape in terms of visual appearance and, to a minor extent, noise production. The impact on local residents however is considered very limited, due to low population density in the immediate area.

## 5.13 Environmental diagnosis

The report by Dr. Flores gives an environmental diagnosis of the area of the site before the project has been installed. The following quote from the report [23] is still relevant.

“Impact prediction and impact assessment of a project require knowledge of present and former conditions of the site, nature inherent variation and scientific uncertainty. Also, project impact combination with those of other existing projects must be taken in consideration. The initial disturbance in the area was produced by deforestation and cattle, with the forests being substituted by pastures, and native fauna being replaced by cattle and horses. Later, the successive interventions produced by the hydroelectric infrastructure built by ICE have been consistently increasing the cumulative negative effect on the area. It should be noted that Arenal, Corobicí, Sandillal, and Cote hydroelectric projects are in the area of direct and indirect impact, as well as three wind farms (Tierras Morenas, Arenal and Tejona), and several small private hydroelectric projects. Those projects require transmission lines, new roads, dams, reservoirs, tunnels and others, plus mobilization of small human settlements. Summarizing, the Arenal-Tejona area has been subjected to a continuous negative and accumulative effect with deep environmental and socio-economic repercussions. Climate and landscape have been changed. Today, major activities are tourism and electric generation. Tourists like to visit the hydroelectric infrastructure; the Arenal reservoir and Lake Cote are used for recreational boating, fishing, water skiing and wind surfing. Hotels use the scarce and small forest patches for horse rides and bird watching. Small properties are disappearing, as well as livestock and agriculture. Pastures hardly support a head of cattle per hectare and agriculture is mainly for survival.

When ICE built the Lake Arenal reservoir, the lake area increased from 26 $km^2$ to 86 $km^2$. The construction of artificial lakes promotes climatic changes in the neighboring areas [32]. The Arenal reservoir construction produced, within other effects, a modification in wind intensity. Northwest trade winds increased their speed consistently in the Tejona area [33]. In addition, wind speed diurnal variation became smaller than that registered before reservoir construction [34]. Paradoxically, the environmental changes introduced by the Arenal reservoir construction converted the Tejona area in an optimal site for eolic plants. This fact reiterates the uncertainty of impact prediction."

[32] Ackerman, W.C., White, G.F. & Worthington. E.B. (Eds.) 1973 Man made lakes: their problems and environmental effects. Geophys. Monograph. 17. Amer. Geophys. Union.

[33] Fernández, W., Chacón, R.E. & Melgarejo, J.W. 1986 Modifications o fair flow due to the formation of a reservoir. J. Climate and Applied Meteorology 25: 982-988.

[34] Fernández, W., Chacón, R.E. & Melgarejo, J.W. 1986 Modifications o fair flow due to the formation of a reservoir. J. Climate and Applied Meteorology 25: 982-988.

# 6. Evaluation of the environmental impacts of the Tejona wind farm

## 6.1 General

The expected environmental impacts have been assessed both for the Montecristo and the Altamira ridge. In the description of the environmental impacts during the disctinctive phases of installation, operation and decommissioning, the impacts are grouped per type of effect.
Since the construction of the 20 MW wind farm has already begun at the onset of the study and has been completed at the time of this report's field investigations, the influence on the above-mentioned aspects has already taken place. As baseline situation, the situation before any work was done on the windfarm, the earlier executed EIA " Informe Preliminar" will be taken. [1]
The study conducted in 1993 [1] concluded that although the environment would be affected during the construction phase of the project, none of the effects were considered to be severe or unmitigable. During the operating stage of the project, the primary impact identified was the visual impact of the turbines and towers. The following sections provide comments on the environmental concerns and benefits expected to be associated with this project complementary to the previous study.

## 6.2 Macro ecological effects

Above all other environmental impacts, the project is very beneficial for the environment because of the positive effects of wind energy on the avoidance of green house gas emissions and avoided depletion of natural resources.

### 6.2.1 Avoided Green house gas emissions

The estimated amount of $CO_2$ reduction assuming flawless operation is 800,000 Tonnes in the total project lifetime of 20 years, if the plant will be generating around 81 GWh per year (see paragraph 4.3.2. ).

### 6.2.2 Positive life cycle effect

The estimated amount of energy required for realising the project (essentially for manufacturing the wind turbines) is harvested back in less than one windy season.

### 6.2.3 No depletion of natural resources

Besides the reduction of emissions in connection with thermal generation, the implementation of the plant will save fossil fuel and will avoid the corresponding pollution in transportation and conversion of the fossil fuel. In addition, a unique characteristic connected with the hydropower generation is that the high wind season coincides with the dry season that again corresponds with the reduced hydropower plant production. Hence, the wind power plant can reduce the need for thermal generation mainly during the dry period.

## 6.3 Impact on land use

The land use designations for the affected sparsely populated areas near the project site and transmission line corridor include rural, rural residential, and scenic. Residential patterns in the vicinity are primarily dispersed houses in rural settings. Because of the high winds, residences tend to be located in the valleys between the ridge lines and the surrounding land is used for grazing. It is expected, therefore, that few inhabitants would be exposed to any impacts from the project and any impacts would be negligible.

As for the impact on the use of the land for grazing purposes, the preliminary Environmental Report [1] describes the situation as follows: "The vegetation at the proposed site is primarily grass, with a few patches of trees in the lower valleys between the ridges. The land in the project area is used for cattle grazing, which is compatible with wind power development". It was observed that this activity is indeed continuing after installation of the project, although cattle mostly do not graze on the high ridges, but generally stay at the lower areas.

## 6.4 Acoustic noise Immission

### 6.4.1 General

The acoustic noise immission contours have been determined by Nordteco with the wind power planning software WindPro version 2.3. The results are presented in Fig. 8.

### 6.4.2 Input for the Immission calculations

The following assumptions and characteristics apply:

- The wind turbine supplier has provided the characteristic noise immission of the wind turbine. The immission relevant A-weighted acoustic source power strength measured in accordance with IEC 61400-11 for the Vestas V47 is 45 dBA. This value is valid for a wind speed of 8 m/s. The values have not been modified for the smaller rotor diameter. Because the noise immission increases with increasing diameter, the resulting calculated immission is conservative (that is: the calculated values are probably higher than the actual values).
- The calculations have been done with actual wind turbine position coordinates provided by topographical department of ICE;
- The noise immission is calculated with the programme WindPro, assuming a noise propagation model according to ISO 9613-2.
- The effect of orography (landscape) is taken into account in the calculation of the noise propagation; however the calculation does not take into account the shielding effect of trees, houses or other obstacles.
- Eight noise sensitive areas were determined for the evaluation. These zones are indicated on the map, Fig. 8. The zones were defined as sensitive because they contain small to medium groups of residences, in the vicinity (radius 3 km) around the wind farm. The list of noise sensitive areas with position coordinates is given in table below. Fig. 8 shows the borderline of the noise sensitive zones and also a bufferzone of 300 m around the zone as is used commonly in Europe.

### 6.4.3 Discussion of the results

The contours of the calculated noise emission for values from 35 to 55 dBA are depicted in Fig. 8. Putting forward a minimum level of 45 dBA to be respected at the front of the house, the conditions would not be fulfilled for some residences in the noise sensitive areas 1 (Palma) and zone 3 (a few rural residences in between the two ridges).. The immissions at the position of noise sensitive zone 1 are not influenced, because of the shielding effect of the hill. The entire zone 3 however lies inside the contour of 45 dBA.

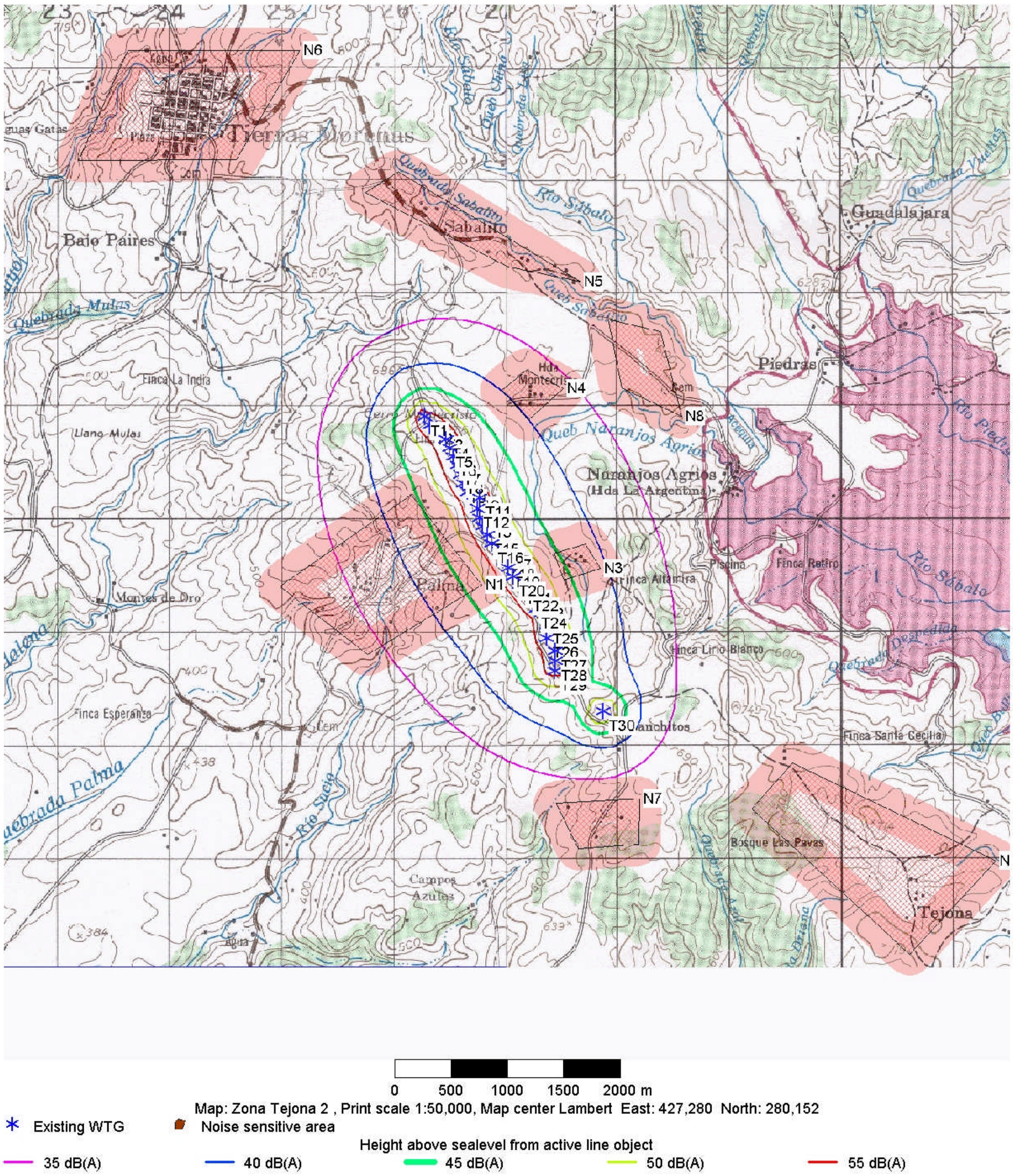


*Fig. 8. Calculated noise contours (WindPro 2.3) of the Tejona 20 MW wind power project. The noise sensitive areas are indicated also on the figure.*

**Sound Level**

| Noise sensitive area | | Lambert | | | Demands | | Sound Level | Demands fullfilled ? | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Name | X | Y | Z [m] | Noise [dB(A)] | Distance [m] | Calculated [dB(A)] | Noise | Distance | Both |
| A | Noise Area 1 | 426,783 | 279,423 | 557 | 45.0 | 200 | 47.5 | No | Yes | No |
| B | Noise Area 2 | 429,408 | 277,674 | 680 | 45.0 | 200 | 30.4 | Yes | Yes | Yes |
| C | Noise Area 3 | 427,515 | 279,463 | 620 | 45.0 | 200 | 47.1 | No | Yes | No |
| D | Noise Area 4 | 427,202 | 280,874 | 620 | 45.0 | 200 | 41.1 | Yes | Yes | Yes |
| E | Noise Area 5 | 427,090 | 282,215 | 680 | 45.0 | 200 | 31.6 | Yes | Yes | Yes |
| F | Noise Area 6 | 424,594 | 283,182 | 680 | 45.0 | 200 | 23.3 | Yes | Yes | Yes |
| G | Noise Area 7 | 427,869 | 277,514 | 660 | 45.0 | 200 | 34.8 | Yes | Yes | Yes |
| H | Noise Area 8 | 428,125 | 281,119 | 622 | 45.0 | 200 | 36.3 | Yes | Yes | Yes |

The following has to be considered in connection with these immission calculations. As stated in the former paragraph, the calculated values are conservative and do not take into account shielding effect from trees etc. It has been verified during a field mission in June 2002 that the wind farm noise (aerodynamic noise) at 1 km at the West side of the ridge was slightly audible, the wind speed was approximately 8 m/s at that moment. The noise was only audible at open spots. Trees, which overrule or shield the wind turbine noise, surround most of the houses in zone 1. From the above simulations and observations, it is concluded that the noise impact of the wind farm on the residents in the area is negligible.

## 6.5 Visual impact

### 6.5.1 General

The expected visual impact of the wind farm was not a critical factor during the project planning. In the early stages of the feasibility study, the intention was to install a large number of small machines, which certainly result in a specific visual appearance. The planned design is quite different from the actual plan implemented, corresponding to a smaller number of large turbines. The wind turbine dimensions are different, the wind farm lay out is different and also the wind turbine rotational speed is different. These aspects all contribute to a lower environmental impact. Moreover, the TWPP project was built next to another large 20 MW windfarm, the visual appearance of which dominates the area (Plantas Eolicas Tejona). The original EIA study [1] concluded that, because of the poor aesthetics of the landscape today (due to grazing), the project could be seen to benefit the landscape by its novelty, and could even be considered as a tourist attraction.

A factor which influences the approach followed in the present study is that the TWPP project 20 MW wind farm was already built when this environmental evaluation study started. This is not normally the case with wind power projects, as visual studies are used to collect evidence in the decision making phase, in order to obtain the environmental and building permits. However, there is also the possibility that ICE will extend the wind farm with another 10MW on the Altamira ridge. The intention of this analysis is to describe the present circumstances and to provide a useful tool for creating a basis for a better overview and a physical evidence to facilitate future decision-making. Annex 6 includes an example that shows what could happen, in visual intrusion terms, for possible 10MW extension.

Hence it has been decided to base the discussion of the visual effects of the wind farm in this study on pictures of the 20MW plant as built on the Montecristo.

Note: Because of the large file size, the pictures referred to in this section have been put in a separate annex (Annex 4).

### 6.5.2 Visualisation of the 20 MW wind farm from selected camera positions

Various pictures (see Annex 4) are showing the appearance of the wind turbine from different camera positions and angles relative to the wind farm. The pictures speak for themselves. In general, the wind farm follows the natural contours of the landscape, rather than imposing a line in the landscape, which would be quite intrusive because of the rather substantial length of the row.

#### 6.5.2.1 Local Landscape

The Guanacaste landscape is characterized by the presence of tropical dry forests and tropical moist forests, among others. The area where the wind power projects are located has a strong deforestation degree because of local agriculture and several farms. The former vegetation was changed into grass and pastures, in order to feed animals principally cattle and cows.
The first visual characteristic on the landscape in the Tierras Morenas area is the presence of a man-made lake. Apparently, this artificial lake has made a great impact on the surrounding areas, changing the visual aspect in a deep way. Not only the landscape, but human habitat and animal wildlife have been affected. Under this scenario, local wind turbines represent a relatively low impact on neighbouring areas.
In all areas within close proximity to the project, the main landscape type consists of small hills, many of them partially covered by few areas that remain the former forest-type landscape. This characteristic of hill-covered terrain affects the visualization of the actual wind power project because of line sight intersection with the projects locations along roads and near human settlement. The Palma town is the closest human settlement located on the west side of La Tejona Wind Power Project, and its visual intrusion because of wind turbines is highly dependent on the position taken within the town. Complex terrain together with trees and the position of the settlement in a lower position than La Tejona project makes the visualization a highly subjective task. The relatively high transit roads and nearest locations were selected as preferred as points of capture for photos to create an impression of landscape intrusion.

#### 6.5.2.2 Photomontage procedure

As there are several existing wind farms operating in the vicinity, the visual effect of one new project among several existing projects is less intrusive compared with a single new project.
With a special technique that uses a computer to generate artificial wind turbines, they can be placed in locations and can be placed in proposed locations for future wind farms.
The actual algorithm to construct the visualization followed a very structured sequence. There were some places selected to present an actual view of the present wind farm, from points considered as affected by visual intrusion. For every place, a picture was taken and their respective settings were registered for calibration of software use.[35].

Every individual will assess the landscape intrusion subjectively. It’s considered that tubular towers are better looking than lattice ones; of course this appreciation corresponds to specific subjective observers. Both types of towers can be found in area of Tierras Morenas.

[35] Other points were selected to construct the artificial representation of future wind farm. See also Annex 6 which has a picture that can be used as reference of possible effects on landscape view, produced by a simulated 10MW extension should it be added to the TWPP project.

### 6.5.3 Determination of the zones of visual influence (ZVI)

#### 6.5.3.1 General

Another technique used for the assessment of the visual impact of a wind farm is determining the amount of area from which the wind farm is visible. This task was also conducted using the wind farm-planning tool WindPro. The Zones of Visual Influence (ZVI) module of WindPro calculates and documents the visual impact of wind turbines in a landscape. This was made by identifying the spots from where one or more wind turbines can be seen, and by calculating the percentage of a given area from where a given number of wind turbines can be seen. In this way, a ZVI analysis provides background material for environmental impact assessments of wind energy projects.

#### 6.5.3.2 ZVI method applied to the 20MW Tejona project

The calculations were based upon a digital 3D model of the landscape, established from digital height contours. Furthermore, local obstacles (e.g. forests) are used. The following information was used to perform the analysis:

- Position coordinates of the wind turbines;
- Hub height and rotor diameter of the wind turbines;
- Digital height contour map;
- Local obstacles (with porosity lower than 0.3);
- Surface objects (forests, cities) with defined elevations above the terrain.

The assumptions for the calculation are summarized below.

**Assumptions for ZVI calculation**

| | |
|---|---|
| Center for calculation | Lambert East: 426,774 North: 280,011 |
| Width of calculation area | 4,000 m |
| Height of calculation area | 4,000 m |
| Calculation step | 50 m |
| Eye height | 1.7 m |
| Calculation area | 1,600 ha |
| Highest relevant visible part of a WTG | Hub height + ½ rotor diameter |
| Obstacles used in calculation | 0 |
| Height contour object used in calculation | Height Contours: oro_rouOriginal.map |
| Area object(s) used in calculation | Area 1 water |
| New WTG's used in calculation | 0 |
| Existing WTG's used in calculation | 30 |

The analysis has been done for an area of 4 km x 4 km; any other size of area can be taken by the method. Furthermore, the existing wind turbines of the other wind farms have not been take into account in the calculation.

6.5.3.3 Calculation results

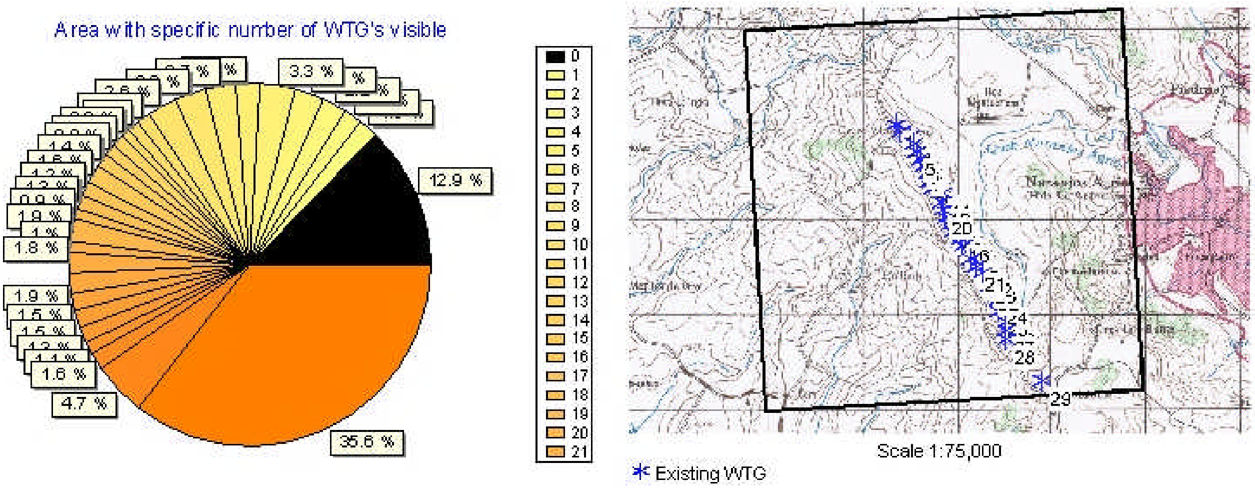


*Fig. 10 Percentage of area versus number of visible wind turbines for the 20 MW Tejona wind energy project.*

Fig. 10 shows the percentage of area from where which turbines can be seen. It shows that in the defined area no wind turbines can be see in 13 % of the area, and that almost 50 % of the area can see 23 or more wind turbines. This is quite logical due to the relative high elevation of the wind farm.

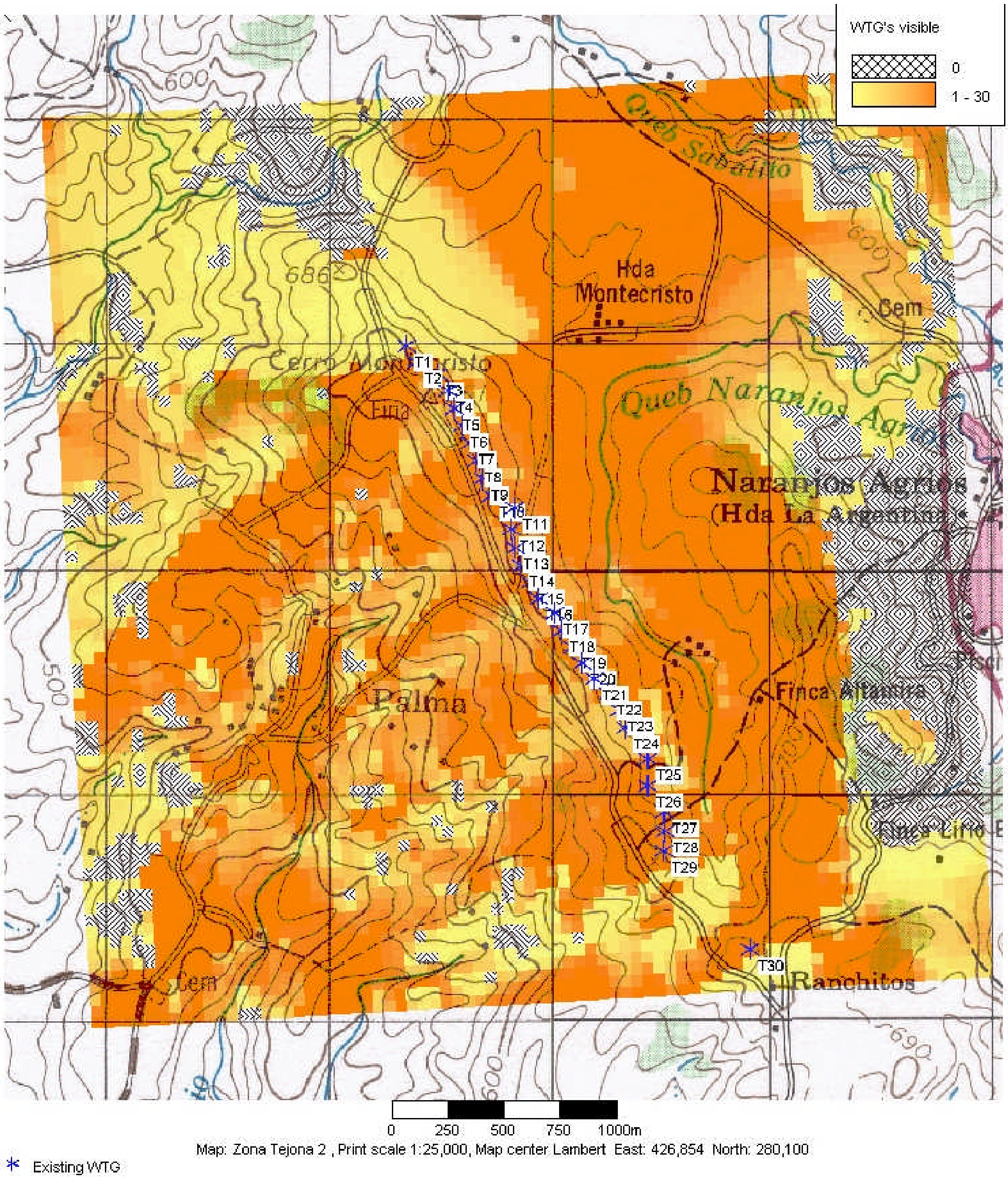


***Fig. 11*** *Indication of visibility of the 20MW Tejona wind farm in the defined area.*

The mapping of the visibility of the project is given in Fig. 11. The percentage of visibility of the wind farm (in fraction of total number of turbines) is indicated in colour code. This figure also shows that for the defined area the wind farm is highly visible. The figure does not take into full account the screening by trees. This would imply a thorough additional effort in environmental mapping, which, in view of the existing public acceptance of the project, would be purely academic and not cost effective.

### 6.5.3.4 Discussion and conclusions on visual influence

The wind farm is highly visible in the environment. The analysis has not taken the screening effect of forests into account in a very detailed way, so the actual impact is less than shown on the pictures. Furthermore, already existing wind farms in the vicinity have significantly influenced the visual characteristic of the area. The visual impact of the actual installations is considered to be less than the planned visual impacts investigated during the original EIA study. The present calculation is included in the report to illustrate the present conditions using sophisticated assessment techniques and the possible use of the ZVI method in assessments for further expansion of wind energy in the area.

### 6.5.4 Determination of shadow effects

This aspect is not relevant in the project because of the distance of the houses to the wind farm. No hindrance is expected.

## 6.6 Environmental risks

### 6.6.1 General

The environmental risks caused by the presence of the wind farm as assessed in this paragraph were related to the following aspects:

- Labour safety for workforce;
- Safety for residents and people present in the neighbourhood;

### 6.6.2 Wind turbine safety

As a rule, in order to ensure safety for the environment, wind turbines should comply with IEC 61400-1. This standard describes the required procedures and measures during design, manufacturing, transportation, installation, operation and maintenance of wind turbines. Compliance with the standard is verified in the type certification of the wind turbine and in the project certification. The applied wind turbine type has been certified, as well as its implementation on the specific site, taking into account the specific environmental conditions. That is to say that besides the normal environmental conditions, the design of the wind turbines and the wind farm takes into account the high average wind speeds, slightly increased levels of acidity, and the risk of earthquakes. The latter point is taken care of by quite heavy dimensioning of the foundation.

### 6.6.3 Safety for workforce and residents

Measures taken to maximise safety for labourers (and people living in the neighbourhood) during construction, commissioning and operation & maintenance of the wind farm are described in procedures, both by ICE and Vestas.

Both ICE and Vestas have developed guidelines for environmental management during construction work, installation, operation and maintenance (O&M). These guidelines include measures to maximise safety for labourers and people living in the neighbourhood.

ICE has drafted an Environmental Management Plan (Plan de Gestión Ambiental) in which measures are described to minimize impact on the environment during all above-mentioned stages of development. This plan of action complies with Costa Rican environmental guidelines as given by SETENA [3].

### 6.6.4 Safety during operation and maintenance

Vestas has obtained ISO 14000 certification which deals with environmental management aspects. Training of all employees in environmental aspects of materials used during the development of the project is standard. This was verified by Vestas O&M staff present at the wind farm[36]. In the Tejona Site Manual [7], one chapter is dedicated to health and safety measures, describing all possible events with measures to be taken in case of occurrence.

### 6.6.5 Conclusion

The environmental risk is kept to as low as possible by a combination of wind turbine safety and quality assurance and by implementation of procedures by ICE and Vestas to minimize risks both during construction and operational phase of the wind farm.

## 6.7 Impact on soil and vegetation during construction and operation

### 6.7.1 Impacts during plant construction

Before the project started, the site was only accessible through the use of a four-wheel drive vehicle from several directions on dirt tracks. Road improvements were necessary in order to allow access for heavy equipment during construction and for maintenance purposes. Improvements were made to one access road to the site, which originates near the Arenal substation and powerhouse. Access to the site is possible from several other roads; however, these were not improved as part of the project.

The major impact on the environment (soil and vegetation) during the construction stage of the project resulted from the upgrading of the roads and civil works on the project site itself. The 20MW plant required approximately 18 months of construction for installation of the turbines and towers. The movement of land had a very moderate environmental impact. The installation of the turbines and improvement and construction of roads was mitigated with re-vegetation measures following construction. As a result, the overall impact on the environment is considered very limited.

During the construction phase of the project, traffic increased significantly in the area. The delivery of the turbines and related electrical equipment resulted in approximately 200 truckloads between the main port on the Pacific coast and the project site. An additional 200 truckloads of cement were brought in during the foundation work. Although the number of loads was significant, the duration of the deliveries were extended over a relatively short period. On a daily basis, only a small number of construction workers were traveling to the site.

The re-vegetation plan also addressed relevant aspects in order to reduce erosion and return of the area to its natural state as quickly as possible following construction.

ICE installed a concrete batch plant near the site to provide the concrete for the foundation work. The foundations were built in accordance with ICE’s general practice, backed-up by standards, such as the site manual, which provides amongst others guidelines for environmental protection [14].

The turbines were built and erected in accordance with the manufacturer’s general practice, backed-up by standards, such as the assembly and erection manual. The most important piece of equipment was the main crane (250 tons, hydraulic) for installation of towers and rotors. It was hired from Panama.

[36] Personal communication to Jan de Jongh in June 2002

***Fig. 12*** *The 20 MW wind farm on Montecristo during construction works. The impact due to excavations for foundations and cable trenches can is clearly visible. The revegetation will cover these scars quite soon however, turning it green again.*

The land for the project was originally fenced; however, much of the land was fenced in small parcels. Additional fencing to temporarily limit access for livestock during construction was necessary. There was sufficient area in the vicinity for this type of short-term relocation without significantly impacting either the livestock or the land use.

Trenching was required for the high voltage cables, low voltage cables, and the communications lines. The depth of trenches and shading required was in conformity with the National Electric Code. The high voltage trench runs along the main road between turbines. The communication circuit is separated from the high and low voltage circuits by at least 2 meters to avoid the possibility of electrical noise in the computer monitoring system. The trenches were compacted using backfill techniques.

### 6.7.2 Impacts during plant operation

During the operation of the project, slight increases in traffic results, however this does not create a significant impact on the local transportation system. The wind farm personnel, following strict guidelines of the environmental management plans and manuals, carry out treatment of hazardous waste and other waste.

## 6.8 Electromagnetic interference

This aspect is related to possible disturbance of TV, radar or other airborne EM signal transmission by the presence of the wind farm. According to the Ministerio de Governación y Policía, the project could interfere with radio waves, affecting populations located close to the wind turbines. Although there is no guarantee that the project will not result in electromagnetic interference, wind projects in the United States have not experienced problems with this issue.

Upon request for information from ICE as well as from the Ministerio de Governación y Policía, no specific information on existing radio or wave link locations could be provided.

The actual situation at the project site also confirms this point. The few dispersed farmhouses in the proximity of the wind farm use parabolic dish TV antennas, since no cable television is available. Furthermore no airport, military or other institutions, which might be hindered by the wind turbines, are in the vicinity. The nearest larger town is Tilarán at about 10 km from the Tejona site.

## 6.9 Impact on birdlife

Dr. Eugenia Flores elaborated an expert opinion on the impact of the Tejona wind farm on wild life and birds [23]. About 20 species of birds are mentioned in the report, although she mentions that this list is not exhaustive and other species may visit the area. No endemic, endangered or threatened species were observed. There are several migratory bird species crossing the zone of the wind farm. However, they fly at high altitude and descend on forest patches. They were excluded for this reason. Dr. Flores concludes "...in other projects, birds returned to the site when restoration ends and the project starts the operation phase. Sporadically, a bird could be killed by the windmill rotor blades".

## 6.10 Impact on wildlife

Dr. Flores also gave her expert opinion on the impact of the Tejona wind farm on wild life [23]. According to the report, deforestation and cattle caused the initial disturbance in the Tejona area. Pastures have substituted the forests, and the native fauna disappeared and was replaced by cattle and horses. Later, the successive interventions produced by the hydroelectric infrastructure built by ICE especially the Arenal lake, have consistently been increasing the cumulative negative environmental effects on the area.

Upon site visit of the project, Dr. Flores reported "The Tejona wind farm looks clean and the restoration of the area is almost finished. Project construction did not add much alteration to that already accumulated. Of course, the wind turbines will affect the landscape. The scarce vegetation did not receive a significant negative impact. The native fauna was disturbed long time ago. Part of the remaining animals will come back as soon as human presence and noise are reduced.

As for the impact on Altamira ridge where another 10 MW would be installed, it can be stated that this ridge covered with pastures was intensively disturbed before the establishment of the first wind farm.

During our site visit, howler monkeys were encountered in the vicinity of the wind farm, within less than 1 km (Fig. 13). This can be considered as an indicator that the construction and operation of the wind farm does not have a severe impact on wildlife".

***Fig. 13*** *Howler monkeys observed near the windfarm (Mono Congo)*

## 6.11 Effects on archaeological and historical features

The area where archeological remains might be found - near the hill at the east end of the Montecristo Ridge – has been investigated by Ana Cristina Hernández Alpízar, ref [12]. During preparations of land excavations for foundations, the archeologist carefully investigated several sites, but no evidence of archeological remains was found [12].

***Fig. 14***. *One of the sites considered possibly to be rests of a grave, but no proof was found for it.*

For the future expansion on the Altamira ridge, the same procedure could be followed, i.e. an archeologist could investigate sites during preparations of land excavations for foundations.

## 6.12 Summary of the impacts

| **Impact** | **During construction** | **During operation** |
|---|---|---|
| Macro-ecological | N | Beneficial |
| Land use | N | N |
| Noise | M | M |
| Visual impact | M | M |
| Environmental risks | N | N |
| Soil and Vegetation | M | N |
| Electromagnetic interference | N | ? |
| Birdlife | M | M |
| Wildlife | M | N |
| Archaeological features | N | N |

N = no impact
M = moderate impact

In Table above a brief overview is given of the analysed impacts.

# 7. Mitigation measures

As stated in the former section, the environmental impact is limited to visual impact. Given the degree of environmental impact already existing before the project was implemented, the generally high level of public acceptance for the numerous wind farms present in the area, it is concluded that mitigating measures are unnecessary.

# 8. Environmental management plan (Plan de Gestion Ambiental)

The responsible agent of the environmental management is ICE. A summary of the environmental management plan during construction is given in Annex 5. The environmental management plan during operation was not provided to the authors of the present study.

## 8.1 Executing agent of the measures

ICE is the executing agent of the measures.

## 8.2 Monitoring

The aspects to be monitored should be indicated in the plan of ICE.

## 8.3 Time schedule

The time schedule should be indicated in the plan of ICE.

## 8.4 Environmental Recuperation plan post-operation

The environmental recuperation plan post-operation should be indicated in the plan of ICE.

## 8.5 Contingency plan

The contingency plan should be indicated in the plan of ICE.

## 8.6 Costs of environmental management

The costs of environmental management should be indicated in the plan of ICE.

## 9. Economic adjustment for social and environmental cost

ICE has developed a plan for social support in the area around Tejona, providing direct support to the following communities: La Palma, Parcelas de Quebrada Azul, Los Ranchitos, Sabalito and Tierras Morenas. The scope of influence of the Tejona wind farm project is much larger however and extends to the districts of Tilarán, Santa Rosa, Tierras Moreneas and Libano.
The plan was developed in co-operation with a large number of institutions working in the region, both governmental and non-governmental. The communities were continuously involved. Activities developed included improving school buildings, providing fences around schools for safety reasons, and providing tools and equipment for agricultural projects for schools including training. A full management plan for two years (2000-2002) was also developed see [19]. The total accumulated costs for these activities performed over the years 2001 and 2002 (up to April 2002) were over US$ 58 000 (20.7 Million CRC) [24]. The program was scheduled for completion in September 2002.

## 10. Conclusions

The environmental impacts of the Tejona 20 MW wind farm have been assessed in the framework of the contribution of DGIS to the TWPP project. In addition to the aspects normally investigated in EIA studies in Costa Rica, attention has been paid to issues that were deemed to be relevant to this project (i.e. detailed acoustic noise emission and visual influences on the landscape).
The main conclusion from this assessment is that the project is beneficial for the environment because of effective generation of wind power. Besides avoidance of emissions of greenhouse gases and depletion of natural resources, the project is valorising the use of land which otherwise is considered to have a low economic value. This way of using the available land is to deploy economic activities on such a specific remote site is considered positively. Moreover, the function of generation of wind power in is not in conflict with the existing planological destination of the area. The demonstration value of this wind power project in view of its size and uniqueness of site is high and could facilitate similar projects in the future.
The local environmental impacts during construction and operation were/are limited. The visual appearance of the landscape has changed, however these impacts are less than were originally planned. The effects on birds in the area are unknown but considered to be quite limited. The interference with radio, television, telecom and other electromagnetic waves could not be assessed because of lack of data about existing radiation paths, but does not appear to pose problems. The impact on vegetation, soil, and wildlife is nihil. The environmental risk is kept to a low level by appropriate wind farm design and safety procedures during installation, operation and maintenance.
In view of the low environmental impact, no mitigating measures are considered necessary. The responsible body, ICE, has an environmental management plan in connection with the wind power plant. There are specific plans for the construction phase and for the operational phase. During construction, the plan has been followed. The details of the plan during operation, which also should include environmental monitoring, were not available for review for the present study. No doubt, the Tejona 20 MW wind power project has a high visibility to the society, because of its large size and because it is the first wind power project realised by ICE. It is recommended that the operators undertake detailed, professional monitoring to keep track of the operational performance and environmental impacts.

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## 12. List of Figures



Photographic sources:

Pictures 1, 2, 4, 5, 7, 12 and complete Annex 4: Frans Van Hulle

Pictures 13: Jan de Jongh

Picture 14: ICE
Picture A1 Juan Carlos López

## 13. List of Annexes

# 14. List of Abbreviations

| | |
|---|---|
| AIJ | Activities Implemented Jointly |
| CDM | Clean Development Mechanism |
| DGIS | Directorate General for International Co-operation |
| EIA | Environmental Impact Assessment |
| ICE | Instituto Costarricense de Electricidad |
| IDB | InterAmerican Development Bank |
| IEC | Intenational Electrotechnical Committee |
| IRR | Internal Rate of Return |
| ISO | International Standards Organisation |
| MINEA | Ministry of Environment and Natural Resources |
| O&M | Operation and maintenance |
| PPP-JI | Pilot Projects Programme for Joint Implementation |
| SCADA | Supervisory Control and Data Acquisition |
| SETENA | Secretaria Tecnica Nacional Ambiental |
| TWPP | Tejona Wind Power Project |
| UNFCCC | United Nations Framework Convention on Climate Change |
| ZVI | Zones of Visual Influence |

# ANNEX 1 WIND TURBINE POSITION SPECIFIC DATA

**Position specific data of the 20 MW Tejona wind farm (coordinates, wind, Annual Energy Output AEO)**

| label | X-coord | Y-coord | Alt (masl) | A (m/s) | K (-) | WS (m/s) | Free AEO (GWh/year) | Net AEO (GWh/year) |
|---|---|---|---|---|---|---|---|---|
| 1MC | 426275.6 | 280908.6 | 750.6 | 14.8 | 2.67 | 13.16 | 3,86 | 2,87 |
| 2MC | 426321.1 | 280835.8 | 755 | 15.1 | 2.7 | 13.43 | 3,93 | 2,93 |
| 3MC | 426415.6 | 280781.0 | 755 | 15.5 | 2.68 | 13.78 | 3,98 | 2,96 |
| 4MC | 426464.8 | 280709.6 | 755 | 15.4 | 2.67 | 13.69 | 3,96 | 2,95 |
| 5MC | 426494.6 | 280631.0 | 755 | 15.5 | 2.66 | 13.78 | 3,96 | 2,95 |
| 6MC | 426528.9 | 280554.2 | 750.3 | 15.3 | 2.66 | 13.60 | 3,93 | 2,93 |
| 7MC | 426564.9 | 280477.9 | 745.7 | 14.9 | 2.67 | 13.25 | 3,89 | 2,89 |
| 8MC | 426592.3 | 280398.3 | 734.2 | 14.6 | 2.66 | 12.98 | 3,83 | 2,85 |
| 9MC | 426621.6 | 280319.7 | 719.4 | 14.1 | 2.65 | 12.53 | 3,73 | 2,77 |
| 10MC | 426658.8 | 280244.0 | 705.5 | 13.7 | 2.65 | 12.18 | 3,63 | 2,70 |
| 11MC | 426752.3 | 280188.8 | 705 | 13.5 | 2.65 | 12.00 | 3,56 | 2,65 |
| 12MC | 426748.3 | 280097.9 | 700.8 | 13.4 | 2.64 | 11.91 | 3,53 | 2,62 |
| 13MC | 426767.0 | 280015.1 | 705.1 | 13.8 | 2.64 | 12.26 | 3,65 | 2,71 |
| 14MC | 426792.3 | 279935.0 | 708.8 | 14.1 | 2.65 | 12.53 | 3,72 | 2,77 |
| 15MC | 426833.1 | 279860.3 | 710 | 14.3 | 2.66 | 12.71 | 3,77 | 2,80 |
| 16MC | 426872.2 | 279785.4 | 704.9 | 14.3 | 2.65 | 12.71 | 3,76 | 2,80 |
| 17MC | 426945.8 | 279722.8 | 702.3 | 13.8 | 2.66 | 12.27 | 3,65 | 2,72 |
| 18MC | 426973.5 | 279643.6 | 712 | 14 | 2.66 | 12.45 | 3,69 | 2,75 |
| 19MC | 427022.8 | 279572.1 | 708.2 | 13.9 | 2.67 | 12.36 | 3,69 | 2,74 |
| 20MC | 427065.9 | 279498.3 | 709.8 | 13.8 | 2.68 | 12.27 | 3,66 | 2,72 |
| 21MC | 427125.9 | 279431.1 | 700.7 | 13.6 | 2.67 | 12.09 | 3,60 | 2,68 |
| 22MC | 427185.8 | 279363.8 | 705 | 13.7 | 2.68 | 12.18 | 3,63 | 2,70 |
| 23MC | 427234.6 | 279292.3 | 696.3 | 13.4 | 2.66 | 11.91 | 3,54 | 2,64 |
| 24MC | 427262.3 | 279212.8 | 685 | 13 | 2.65 | 11.55 | 3,42 | 2,54 |
| 25MC | 427366.6 | 279072.0 | 689.3 | 12.4 | 2.65 | 11.02 | 3,25 | 2,42 |
| 26MC | 427348.4 | 278952.9 | 688.9 | 12.4 | 2.65 | 11.02 | 3,25 | 2,42 |
| 27MC | 427435.3 | 278839.5 | 700.2 | 13 | 2.67 | 11.56 | 3,44 | 2,56 |
| 28MC | 427435.3 | 278750.1 | 708.5 | 13.2 | 2.67 | 11.74 | 3,51 | 2,61 |
| 29MC | 427447.6 | 278662.5 | 710 | 13 | 2.69 | 11.56 | 3,44 | 2,56 |
| 30MC | 427884.9 | 278290.3 | 728.7 | 12.7 | 2.71 | 11.30 | 3,37 | 2,51 |
| | | | | | | | 109,85 | 81,72 |

***Correction factors**

| | |
|---|---|
| Wake losses | 0.98 |
| Grid availability | 0.99 |
| M/c availability | 0.93 |
| T&D efficiency | 0.97 |
| Uncertainity factor in modelling & PC | 0.85 |
| Net correction factor | 0.74 |

## *LA TEJONA*

Date / Initials
23/7-02 / LSV

**30** **CONSUMABLES FOR 12 MONTH OF OPERATION BY UNIT(S) OF VESTAS V42-660kW TURBINE(S)**

| *Item No.* | *Description* | *Qty per year* | *Qty for WTG's* | *Qty every 2 year* | *Qty for WTG's every 2 year.* | *Qty every 5 year* | *Qty for WTG's every 5 year.* |
|---|---|---|---|---|---|---|---|
| *CONSUMABLES* | | | | | | | |
| 149047 | AreoShell Calsium, greas 14 a 400 g. | 7.0 | 210.0 | | | | |
| 149189 | Klüber Grafloscon A G 1 Ultra ( 1 kg ) | 1.0 | 30.0 | | | | |
| 149139 | SKF LGWM1 a 400 g. | 6.0 | 180.0 | | | | |
| 149190 | GREASE KLÜBERFLEX BEM 41-134 a 400 g | 1.2 | 36.0 | | | | |
| 149064 | Optimol Optipit a 400 g | 1.5 | 45.0 | | | | |
| 149092 | Gear oil, Texaco Meropa 320 in liters | 0.0 | 0.0 | 180.0 | 5400.0 | | |
| 149115 | Texaco Rando HDZ32 oil, hydraulic system in liters | 0.0 | 0.0 | | | 60.0 | 1800.0 |
| 149107 | Shell Tivela SC oil, yaw gear in liters | 0.0 | 0.0 | | | 8.7 | 261.0 |
| 149074 | Lubricant, RTF, spray a 500 ml. | 0.5 | 15.0 | | | | |
| 188476 | Battery 1,5 v in pcs. | 4.0 | 120.0 | | | | |
| 130552 | Filter, hydraulic in pcs. | 1.0 | 30.0 | | | | |
| 109062 | Filter for gearoil in pcs. | 2.0 | 60.0 | | | | |
| 109113 | Filter, Air insert in pcs. | 1.0 | 30.0 | | | | |
| 106350 | Oil Leak absorber mat in pcs | 2.0 | 60.0 | | | | |
| 198003 | Cleaning paper Tork Multi, 1 piece | 300.0 | 9000.0 | | | | |
| 096181 | Aqua Petrosol, cleaning solvent in liters | 0.5 | 15.0 | | | | |
| 096185 | Drycleaner in liters. | 0.5 | 15.0 | | | | |

paper products.
Steel can / box.
Plasitc tube
Plastic can.
Battery waste.
steel filters

Then we have other effects such as steel and hard plastic from the hydraulic and electrical units.
All these grease and oil products will be mixed with paper in the same bag during service. When we are talking about change of oil every 2 and 5 year it will be seperatly

Description of yearly needed consumables for operation and servicing of the wind farm (Vestas)

# ANNEX 3 ICE WORK FORCE PLANNED FOR CONSTRUCTION

## Labour force[37]

**Tejona Wind Power Project**

**Workforce needed for 2001 period**

**Planning and control office**

| **Bi-weekly period year 2001** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Administrative services** | | | | | | | | | | | | | | | | | | |
| AD-A3 | | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| ASEA-A | | | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| AUAL-B | | | | | | | | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| AUCO-A | | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| COCI-1A | | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DEAL-1A | | | | | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| VIGI-1B | | | | | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **TOTAL** | **0** | **0** | **0** | **0** | **1** | **4** | **4** | **5** | **12** | **12** | **12** | **12** | **12** | **12** | **12** | **12** | **12** | **12** |
| **Mechanical Mounting** | | | | | | | | | | | | | | | | | | |
| AUMS-2B | 12 | 12 | 12 | 18 | 26 | 26 | 26 | 26 | 26 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| MEMO-2C | 3 | 3 | 3 | 5 | 9 | 9 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| PINT-B | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| TE-C1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **TOTAL** | **17** | **16** | **16** | **24** | **36** | **36** | **32** | **32** | **32** | **24** | **24** | **24** | **24** | **24** | **24** | **24** | **24** | **24** |
| **Electrical mounting** | | | | | | | | | | | | | | | | | | |
| AUEM-B | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 5 | 5 | 5 |
| ELMO-3B | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 5 | 5 | 5 |
| **TOTAL** | **23** | **23** | **23** | **23** | **23** | **23** | **23** | **23** | **23** | **23** | **23** | **23** | **23** | **23** | **23** | **10** | **10** | **10** |
| **Civil works** | | | | | | | | | | | | | | | | | | |
| ARTE-2B | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| ARTE-2C | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 |
| AUAR-C | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| PEON-C | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| TEC-B6 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| **TOTAL** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** |
| **Transport and machinery** | | | | | | | | | | | | | | | | | | |
| AUMP-C | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| COVE-1C | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| ICPC-3B | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| MESE-4B | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **TOTAL** | **7** | **7** | **7** | **7** | **7** | **7** | **7** | **7** | **7** | **7** | **7** | **7** | **7** | **7** | **7** | **7** | **7** | **7** |
| **TOTAL PROG.** | **123** | **122** | **122** | **130** | **143** | **146** | **142** | **143** | **150** | **142** | **142** | **142** | **142** | **142** | **142** | **129** | **129** | **129** |

[37] Internal ICE codes. Bi-weekly periods are related to half-month periods (e.g. bi-weekly period 26 is from December 15 until December 31 2001).

# ANNEX 4 PHOTOVISUALISATION (SEPARATE ELECTRONIC FOLDER)

***The folder contains***

- Pictures of the 20 MW wind farm as built;
- Photovisualisation of the hypothetical 10 MW extension

ANNEX 5 ENVIRONMENTAL MANAGEMENT PLAN IN CONSTRUCTION PHASE

| | | | | | | |
|---|---|---|---|---|---|---|
| PLAN DE GESTION AMBIENTAL | | | | | | |
| PROYECTO EÓLICO TEJONA | | | | | | |
| MEDIDAS AMBIENTALES | FACTOR | TIPO | DURACION | | | RESUMEN |
| | IMPACTADO | MEDIDA | (MESES) | EJECUTOR | MONITOREO | DE LA MEDIDA |
| CAMINOS (CREACION DE NUEVOS Y MEJORAMIENTO) | | | | | | |
| Inventario y permisos forestal | vegetación | L | 0.5 | 3 | 1 | Requisito exigido por Ley del Ambiente |
| Selección de maquinaria en buen estado | atmósfera | P | 6 | 2 | | Orientado a minimizar emisiones |
| Construcción de accesos | sist. hídrico | P | 6 | 2 | 1 | Minimizar aporte sedimentos |
| Establecimiento de área de maniobras en zona de trabajo | personal ICE | P | 6 | 2 | 2 | Minimizar compactación y accidentes laborales |
| Disposición de materiales de desecho en botadero | sist. hídrico | P-M | 6 | 2 | 1 | Prevenir daños a la infraestructura y accidentes |
| Adecuación del drenaje superficial en escombrera | carretera | P, M | 6 | 2 | 1 | Canalizar aguas para no dañar carretera |
| Dotar al personal de equipo de seguridad necesario | personal ICE | P | 6 | 2 | 1 | Evitr accidentes laborales |
| Restringir acceso de personal no autorizado al área de trabajo | público | P | 6 | 2 | 1 | Evitar accidentes a terceros |
| Dispositivos de seguridad vial | transito vial | P | 6 | 2 | 1 | Evitar accidente de circulación |
| Depósitos de basura | suelo | P | 6 | 2 | 1 | Dejar el sitio en su estado original/prevenir cont. |
| CONSTRUCCION DE FUNDACIONES | | | | | | |
| Selección de maquinaria en buen estado | atmósfera | P | 6 | 2 | 1 | Evitar emisiones y ruido excesivo |
| Precaución en rabastos de combustible | suelo, sist. Hídrico | P | 6 | 2 | 1 | Evitar contaminación por derrame |
| Disposición de materiales de desecho en botadero | sist. hídrico | P | 6 | 2 | 1 | contener detritos para evitaraccidentes/daños |
| Conformación de relleno | carretera y viajeros | P | 6 | 2 | 1 | Estabilizar el depósito de detritos |
| Adecuación del drenaje superficial | carretera | P, M | 6 | 2 | 1 | Canalizar aguas para no dañar carretera |
| Establecimiento de área de maniobras en zona de trabajo | personal ICE | P | 6 | 2 | 2 | Minimizar compactación y accidentes laborales |

| | | | | | | |
|---|---|---|---|---|---|---|
| Dispositivos de seguridad vial | transito vial | P | 6 | 2 | 1 | Evitar accidente de circulación |
| Personal de seguridad para tránsito | transito vial | P | 6 | 2 | 1 | Ordenar el tránsito para evitar accidentes |
| Dotar al personal de equipo de seguridad necesario | personal ICE | P | 6 | 2 | 1 | Evitr accidentes laborales |
| | | | | | | |
| MONTAJE DE EQUIPO EÓLICO | | | | | | |
| Dotar al personal de equipo de seguridad necesario | personal ICE | P | 6 | 2 | 1 | Evitar accidentes laborales |
| Restringir acceso de personal no autorizado al área de trabajo | público | P | 6 | 2 | 1 | Evitar accidentes a terceros |
| Dispositivos de seguridad vial | tránsito vial | P | 6 | 2 | 1 | Evitar accidente de circulación |
| Depósitos de basura | suelo | P | 6 | 2 | 1 | Dejar el sitio en su estado original/prevenir cont. |
| TIPO DE MEDIDAS: P=preventiva, M=mitigadora, C=compensación L= Legal | | | | | | |
| MONITOREO: 1=regente ambiental (Centro de Gestión Ambiental,ICE), 2= personal de P.E. Tejona | | | | | | |
| EJECUTOR: 1=regente ambiental (Centro de Gestión Ambiental,ICE), 2= personal de P.E. Tejona 3= MINAE | | | | | | |
| | | | | | | |
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## ANNEX 6 HYPOTHETICAL VISUALISATION OF THE PROJECTED 10 MW EXPANSION

The main purpose of the photo-visualisation is to create a self-impression by the observer about the landscape intrusion of the proposed 10 MW wind power project expansion. This task was analysed using a specialized software package, WindPro version 2.3.
The principal tool used to create the projection was the photomontage technique. Such a process has at its base a computer calculus made over a calibrated picture, specifically collected for this task. All general settings such as camera focal lens, iris aperture and even daylight conditions were taken into account for the final projection of future wind turbines.
There was no wind farm layout defined for proposed 10 MW expansion at the time of this study. Taking into consideration that Altamira hill follows a line of available terrain, the proposed layout of the artificial landscape follows the same configuration of the actual wind farm. Such disposition consists on an irregular line that uses a 2 diameter spacing between each turbine. The wind turbines were placed on the top of the hill. This rule was broken in some cases because of local terrain constraints.
The Altamira simulation is based on subjective perceptions of future proposed 10 MW expansion based upon the correlation with actual disposition of wind turbines at Montecristo hill.

***Fig. 13A1***. *Computer simulation of hypothetical 10 MW wind farm extension, on Altamira ridge.*

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| **Title** | **Evaluation of the Environmental Impact of the 20 MW Tejona Wind Power Project, Costa Rica** |

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| **Principal(s)** | Essent Duurzaam B.V. |
| **ECN project number**<br>**Principal's order number** | 7.4657.04.02<br>4500087587 |

## Summary

The environmental impact assessment (EIA) study was executed within the framework of the 20 MW Tejona Wind Power Project of the energy utility company, Instituto Costarricense de Electricidad (ICE), in Costa Rica. The project is located on an extremely wind-resourceful site (annual average wind speed in excess of 13 m/s) in the province of Guanacaste in the North of Costa Rica. The contents and scope of the study follow relevant EIA requirements in Costa Rica, and some EIA requirements from the government of the Netherlands. The study provides an update to the original EIA study (1993) taking into account developments in the legal requirements, the methods and tools for environmental assessments, and adjusted to the present conditions and wind turbine technology actually used.
The report gives a detailed description of the Tejona 20 MW Wind Power Project. Besides technical specifications, details are given about the parties involved, organisation, resources used, regulatory framework and financial aspects. Site-specific characteristics relevant for environmental consideration in Tejona are described and briefly analysed. Besides climatic parameters, these include the geological, soil, vegetation, fauna, and archaeological and socio-economic characteristics. The study provides systematic analysis of environmental impacts of the 20 MW Tejona wind power project. The beneficial influence of greenhouse gas abatement is described. Aspects of land use, acoustic noise emissions, visual impacts, safety, impact on soil and vegetation, impacts on birds and wildlife and on archaeological features are discussed. A summary of the impacts is given. The planning aspects in view of an environmental management plan are listed but are not analysed in detail.
The findings are influenced by the fact that wind energy already is integrated in the local environment in the form of a number of large projects. It is concluded that the environmental impact of the project is positive in several important aspects. The few detrimental impacts that occur are considered to be negligible or limited.

**Key words**
Wind energy project, environmental impact assessment, Costa Rica

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