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Analysis of Clean Development Mechanism for Dernah Wind Farm (I) Project (Libya)by Using AM0019 Methodology

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ABSTRACT

Since the Kyoto Protocol came into effect on Feb 16, 2005, the Clean Development Mechanism (CDM) has experienced significant global growth. This mechanism enables developing countries to actively engage in combating climate change by implementing projects aimed at reducing Greenhouse Gas Emissions (GGEs). In 2010, Libya established the Commission of the Designated National Authority (DNA) to oversee the implementation of the CDM. This move was made as part of Libya's efforts to develop a range of projects that qualify for CDM and contribute to reducing GGEs.

The main motivation for conducting this study was the absence of Libya's involvement in global-level CDM projects, as evidenced by the United Nations Framework Convention on Climate Change (UNFCCC) annual reports. Additionally, the failure to recognize the significance of CDM in influencing decisions regarding investments in wind energy. This work aims to investigate the use of CDM in Dernah wind farm (I) project (Libya). The study used a suitable CDM methodology, AM0019 with the appropriate tool (03-V3), calculated as CO2 reductions and Certified Emission Reductions (CERs). The results of CDM analysis are as follows: CO2 reductions = 362,201.82 tCO2e/year and CERs for the first ten years of the age of the proposed wind farm (Dernah Wind Farm (I)) (CERs10y)= 1,687,898,590 LD (320,838,371.8 €) for the first ten years, likewise CERs20y= 3,375,797,180 LD (641,676,743.5 €) during the entire life (20 years) of the proposed wind farm. Based on this results, it can be concluded that the project will be highly cost-effective, this will lead to lower electricity prices for consumers and higher profits for the project owners. Therefore registering wind energy projects as CDM projects and earning CERs is the most practical way to promote wind energy. The findings of this study could be valuable for policy makers and project developers who are interested in CDM wind projects.

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تحليل آلية التنمية النظيفة لمشروع مزرعة رياح درنة (I) (ليبيا) باستخدام المنهجية AM0019

سعد حبيب هادي البهادلي.

ملخص: منذ دخول بروتوكول كيوتو حيز التنفيذ في 16 فبراير 2005 م، شهدت آلية التنمية النظيفة (CDM) نموًا عالميًا كبيرًا. وتُمَّكن هذه الآلية البلدان النامية من المشاركة بنشاط في مكافحة تغير المناخ من خلال تنفيذ المشاريع التي تهدف إلى الحد من انبعاثات الغازات الدفيئة (GGEs) في عام 2010م، أنشأت ليبيا الهيئة الوطنية المخولة (DNA) للإشراف على تنفيذ آلية التنمية النظيفة، وجاءت هذه الخطوة كجزء من جهود ليبيا لتطوير مجموعة من المشاريع المؤهلة لآلية التنمية النظيفة والمساهمة في الحد من انبعاثات الغازات الدفيئة .وكان الدافع الرئيسي لإجراء هذه الدراسة هو غياب مشاركة ليبيا في مشاريع آلية التنمية النظيفة على المستوى العالمي، كما يتضح من التقارير السنوية لاتفاقية الأمم المتحدة الإطارية بشأن تغير المناخ (UNFCCC) . بالإضافة إلى ذلك، عدم إدراك أهمية آلية التنمية النظيفة في التأثير على القرارات المتعلقة بالاستثمار في طاقة الرياح. تهدف هذه الدراسة إلى بحث استخدام آلية التنمية النظيفة في مشروع مزرعة الرياح في درنة (ليبيا). استخدمت منهجية آلية التنمية النظيفة AM0019 مع الأداة (03-V3) المناسبتين لحساب تخفيضات ثاني أكسيد الكربون وتخفيضات الانبعاثات المعتمدة (CERs) . نتائج تحليل آلية التنمية النظيفة هي:

تخفيضات ثاني أكسيد الكربون = 362,201.82 طن ثاني أكسيد الكربون/سنة و شهادة الانبعاثات المعتمدة للسنوات العشر الأولى من عمر مزرعة الرياح المقترحة (مزرعة رياح درنة-1) ($CERs_{10y}$) = 1,687,898,590 LD (320,838,371.8 €) وبالمثل شهادة الانبعاثات المعتمدة طوال العمر الكامل (20 عامًا) لمزرعة الرياح المقترحة ($CERs_{20y}$) = 3,375,797,180 LD (320,838,371.8 €) . وبناءً على ذلك، يُستنتج أن المشروع سيكون فعالاً للغاية من حيث التكلفة، وسيؤدي ذلك إلى انخفاض أسعار الكهرباء للمستهلكين وزيادة الأرباح لأصحاب المشروع، وبالتالي فإن تسجيل مشاريع طاقة الرياح كمشاريع آلية التنمية النظيفة والحصول على شهادات خفض الانبعاثات هي الطريقة الأكثر جدوى لتعزيز طاقة الرياح. يمكن ان تكون نتائج هذه الدراسة ذات قيمة كبيرة لصانعي السياسات ومطوري المشاريع المهتمين بآلية التنمية النظيفة في مشاريع طاقة الرياح.

1. Introduction

The Clean Development Mechanism (CDM) was one of three mechanisms established by the Kyoto Protocol in 1997 to meet the Climate Convention objective of stabilizing greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The other two mechanisms are Emissions Trading and Joint Implementation, both of which are not applicable to developing countries. The CDM has two objectives; first to assist non-Annex I (are mostly developing countries. List can be referred to in the Climate Convention) parties in achieving sustainable development and in contributing to the ultimate objective of the Climate Convention, and the second to assist Annex I parties (include developed countries and countries in transition, who have commitments for emission reductions under the Climate Convention)with commitments under the Protocol in reducing greenhouse gas emissions to comply with their reduction targets. The basic principle of the CDM is simple; developed countries can invest in low-cost abatement opportunities in developing countries (such as Libya) and receive credit for the resulting emissions reductions, thus reducing the cutbacks needed within their borders. While the CDM lowers the cost of compliance with the Protocol for developed countries, developing countries will benefit as well, not just from the increased investment flows, but also from the requirement that these investments advance sustainable development goals. The CDM encourages developing countries to participate by promising that development priorities and initiatives will be addressed as part of the package. This recognizes that only through long-term development will all countries be able to play a role in protecting the climate. The CDM can contribute to a developing country's sustainable development objectives through:

- Transfer of technology and financial resources;
- Sustainable ways of energy production;

- Increasing energy efficiency and conservation;
- Poverty alleviation through income and employment generation;
- Local environmental side benefits.

There are many studies that dealt with many topics for wind energy in Libya. Hiba Shreif et al. [1] Analyze the wind energy resource potential at Hun, Wind data was analyzed using different statistical models and calculations were performed to forecast wind energy& power density at the site. Energy production was estimated using different wind turbines The wind data are measured at four heights of (20 m, 40m, 60m and 61m) above ground level. The analysis showed that the annual average wind speed is 5.69 m/s and the power density is about 190 W/m2 at 61m height. It could be noticed that at 61m height, the highest scale parameter is 7.25 m/s in April while the lowest scale parameter is 5.71 m/s in October, the wind turbines suitable for this site should be of class III/B. Alhassan A. Teyabeen et al. [2] Estimate the monthly and annual wind power density based on the Weibull distribution using wind speed data collected in Zwara, Libya during 2007 The wind date are measured at the three hub heights of 10m, 30m, and 50m above ground level, and recorded every 10 minutes. The analysis showed that the annual average wind speed are 4.51, 5.86, 6.26 m/s for the respective mentioned heights. The average annual wind power densities at the mentioned heights were 113.71, 204.19, 243.48 W/m2 respectively. Rtemi et al. [3] Design optimize and design a hybrid wind/PV solar power system HOMER simulation program is used to design the off-grid and assess the feasible solution and economic cost. In the off-grid hybrid system, the best option is the fourth scenario, where the capacity shortage is 5% of the 60,385.6 kWh/yr electric load, peaking at 43.45 kw, because the lowest COE is 0.222 $ and the NPC is 168,173 $. The system consists of a 20 kW PV, one turbine of 25 kW, and 72 Hoppecke batteries of 1500.Ah each. The annual share of wind energy was 77%, and solar energy was 22.9%. The estimated excess of electricity was 58.3%. Authors in [4-6] established the fundamentals of localizing the wind energy business in Libya. For many viable wind energy production locations in Libya, the System Advisor Model (SAM) software was used to calculate the productivity of wind farms with a 100 MW capacity. The study's findings showed that the Gamesa turbine, whose capital cost was around (146,916,400 $), had the best economic and environmental indices. The GHG emission rates for all the cities that were targeted ranged from 24-63g GHG/kWh The time needed for carbon to recover ranged from 5.5 to 14.5 months. The expected energy payback time was 14 to 22 months. An LCOE's production costs ranged from 4.8 to 11.1 cents per kWh. Ahmed M. Makhzom et al.[7] Estimate the CO_2 emission factor for the energy industry sector, which includes the oil and refining industry sector, the research also aims to estimate and collect the quantities of carbon dioxide emitted from the primary energy flow path .The Life Cycle Assessment (LCA) methodology adopted in this research. The mathematical analysis showed that the data for the energy industry sector to generate 1 MW-hr of electricity, 291 kg of diesel oil must be burned, and to obtain this amount of diesel, 1,141 kg of crude oil must be refined, where it was found that the total CO_2 emitted was around 1253 kg CO_2 per MWh. The share of the oil sector from the emitted CO_2 was 6.4%, whereas the share of the electricity sector was 93.6% .Previous studies have highlighted the lack of attention given to analyzing the CDM.

The aim and scope of this study is to analyze existing Dernah wind farm (I) located in Libya as hypothetical project implemented under the CDM. It also aims to uncover the significance of the CDM for the Kyoto Protocol in influencing decisions regarding investments in wind energy. The objectives of this study are to focus on the attractiveness of the CDM for a wind power project, which is positioned in Dernah (Libya), through the calculation of Certified Emission Reductions (CERs) and demonstrate the importance of including carbon trading revenues in enhancing the economic competitiveness and investment attractiveness of wind energy projects, which will play a vital role in encouraging and facilitating investments in such projects, in addition to increasing public awareness of the importance of investing in CDM projects, and reinforcing the belief that clean development not only achieves sustainable development by preserving the environment, but also attracts more foreign investments.

1.1. The climate change phenomenon (in brief)

a- Increase in the average temperature of the Earth.
b- Increase in the rate of melting ice and rising sea level.
c- Change in the rates of rainfall.
d- The receding in agricultural areas.
e- Decrease in the amount of water suitable for drinking.
f- Increase in (number and intensity) of storms.

1.2. Dernah Wind Farm (I) Project

The wind farm is located on east coast of Libya, at latitude of 32.45 deg. and longitude of 23.00. The purpose of choosing this site is the high wind speed, easy access to the site, proximity of the port to supply the equipment that would be shipped to the site, proximity to the electric network for electricity interconnection as well as to the cement factory which is close to the wind farm site. Dernah wind farm project is divided into two stages (Wind Farm (I) & Wind Farm (II)), a wind farm of 61.05 MW (1st stage(I)) has been put into construction process in Dernah (Fattaih area) in May 2010 by M.TORRES Spanish Company.

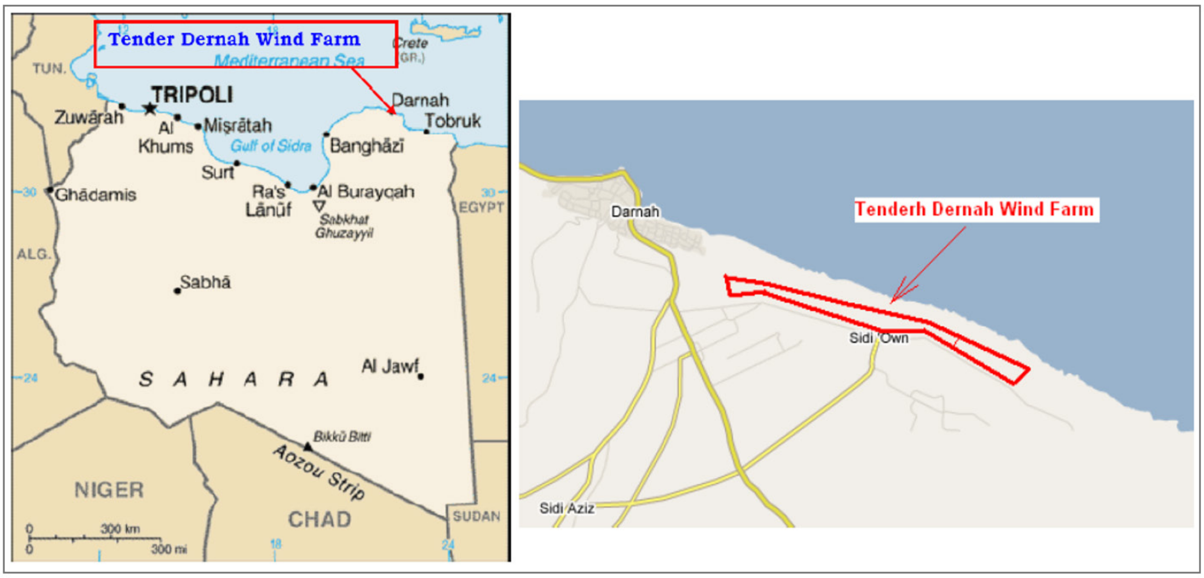

Figure 1. Dernah location [9].

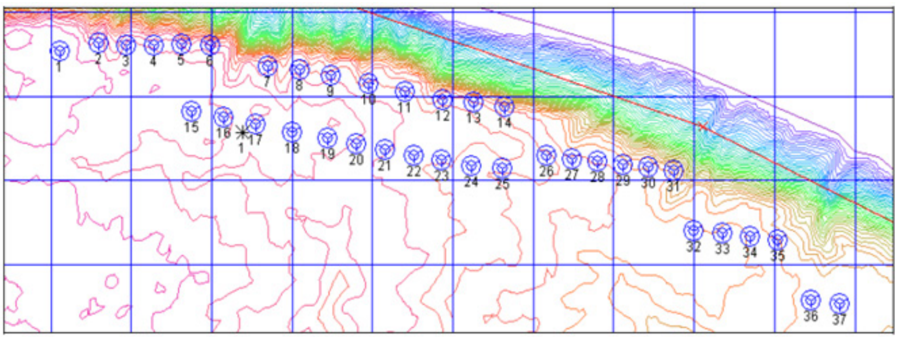

Figure 2. Layout, 37 TWT 1.65/82 wind turbines [9].

Another 60 MW (2nd stage (II)) are scheduled to be finished after 61.05 MW (1st stage (I)). Each with total installation costs of 103 million euros. Dernah Wind farm phase I, consists of 37 wind turbines 1.65 MW each with total installed capacity of 61.05 MW. The wind turbine model is M.TORESS (TWT 1.65/82). The estimated net energy output from the wind farm is 226715 MWh/year [8], Figure 1. shows Dernah location and figure 2. shows Layout of 37 TWT 1.65/82 wind turbines.

1.3. Specifications of M.Toress (TWT 1.65/82) Wind Turbine

Table 1.Shows the specifications of M.TORRES TWT 1.65/82 wind turbine.

Table 1.Specifications of M.TORRES TWT 1.65/82 wind turbine [10].

Rotor	
Diameter	82 m
Swept area	5,365 m2
Number of blades	3
Position	Upwind
Rotor speed	Variable between 6 - 18 r.p.m.
Control	Pitch controlled with independent electrical blade actuators.
Generator	
Type	Variable-speed, direct-drive multipole synchronous generator with independent electrical excitation.
Power	1,650 kW
Voltage	690 V
Nacelle	
Construction	Monocoque in steel
Yaw system	Active system with electrical motors
Corrosion protection	Epoxy coating
Tower	
Type	Tubular conical steel
Hub height	71 m
Corrosion protection	Epoxy coating
Operation Data	
Wind turbine class	IIIa, according to GL(Guideline for the Certification of Wind Turbines)
Cut in wind speed	3 m/s
Cut out wind speed	25 m/s for more than 10 min 32 m/s for more than 0.7 s
Survival Speed	52.5 m/s
Other	
Design life	20 years
Protections	Lightning protection integrated in blades and structure
Control	Optimized with strategies base on QFT adaptable predictable robust control
Power electronics	Two three-phase symmetric and reversible bridges, controlled with IGBT´s
Power quality	According to IEC 61400-21, Low voltage dips ride-through Cos φ variable regulation ≥ 0.94 ,Inductive / Capacitive Optional: Cos φ ≥ 0.90

2. Clean Development Mechanism

2.1. Background

The Kyoto Protocol (KP) under the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in Kyoto (Japan) on 11 December 1997 and entered into force on 16 February 2005. Its ultimate objective is to stabilize greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Towards this general objective, the KP establishes legally binding commitments for the reduction of GHGs produced by Annex I countries (industrialized countries), as well as general commitments for all member countries show figure 3 [11].

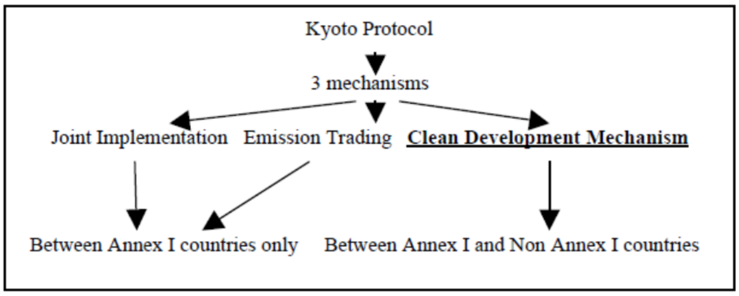

Figure 3. Three mechanisms of Kyoto Protocol [11].

The CDM is one of the mechanisms established by the KP to help industrialized countries meet their reduction targets. Unlike other mechanisms, the CDM promotes cooperation between industrialized and developing countries. It allows industrialized countries to implement projects in developing countries that reduce greenhouse gas emissions (GGEs).

Figure 4. Price development of CER (2019-2022) at the European Energy Exchange [12].

These reductions result in CERs credits, which can be traded and sold. This provides a cost-effective way for industrialized countries to meet their commitments and helps developing countries achieve sustainable development. The CDM specifically encourages investments from industrialized countries in wind power, which not only reduces emissions but also improves the competitiveness of renewable energies against fossil fuel generators. Ultimately, the CDM contributes to addressing the externalities associated with fossil fuel utilization. Figure 4 shows price development of CER (2019-2022) at the European Energy Exchange. Figure 5 shows the trend of types projects registered and registering in CDM and figure 6 shows distribution of registered projects by UNFCCC region, while the figure 7 shows CDM's projects percentage, it is clear the 72% are in the renewables sector, with wind (31%).

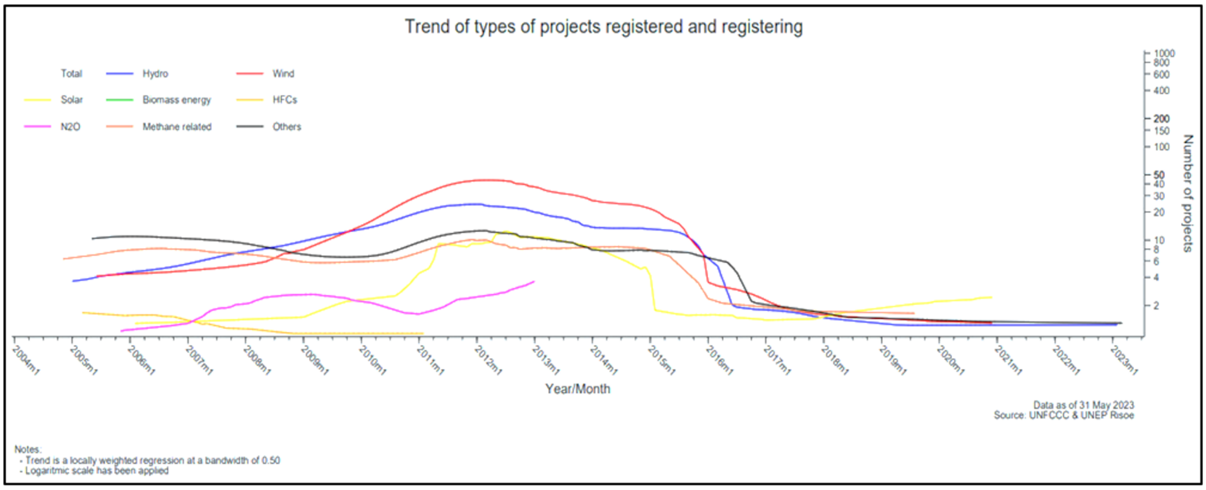

Figure 5. Trend of types projects registered and registering in CDM [13].

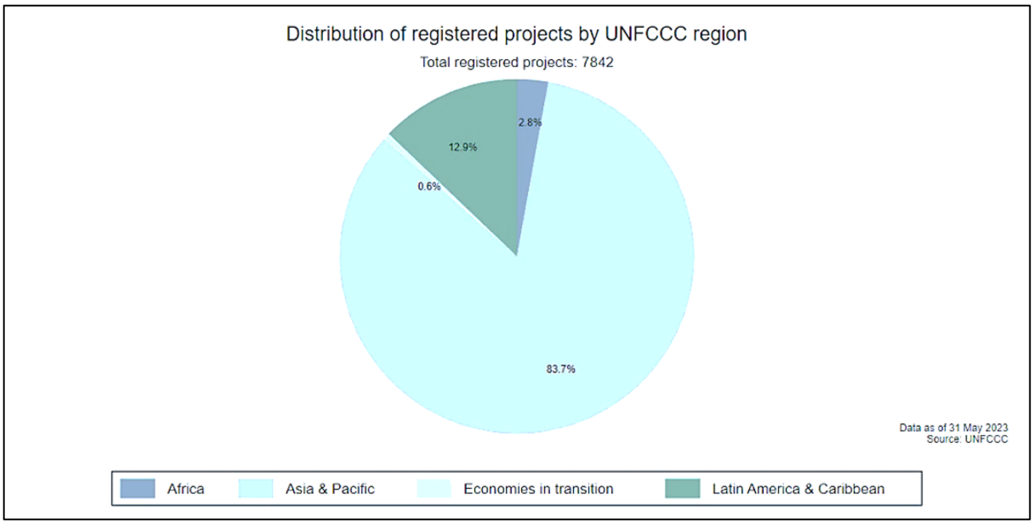

Figure 6. Distribution of registered projects by UNFCCC region [14].

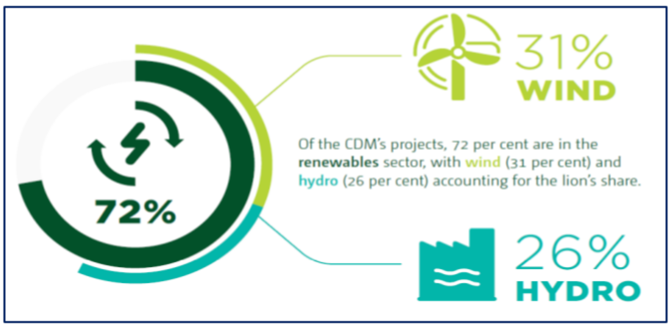

Figure 7. CDM's projects percentage [14].

2.2. National Value and Benefits

From the developing country perspective, the CDM can:
- Attract foreign capital for projects that assist in the shift to a more prosperous but less carbon-intensive economy.
- Encourage and permit the active participation of both private and public sectors in sustainable projects;
- Provide a tool for technology transfer, if investment is channeled into projects that replace old and inefficient fossil fuel technology, or create new industries in environmentally sustainable technologies; and,
- Help define investment priorities in projects that meet sustainable development goals.
- Specifically, the CDM can contribute to a developing country's sustainable development objectives.

Sustainable development benefits could include reductions in air and water pollution through reduced fossil fuel use, especially coal and oil, but also extend to improved water availability, reduced soil erosion and protected biodiversity. For social benefits, many projects would create employment opportunities in target regions or income groups and promote local energy self-sufficiency. Therefore, carbon abatement and sustainable development goals can be simultaneously pursued [15].

3. Libya Status

3.1. Carbon Dioxide Emissions in Libya

Table 2 shows emissions carbon dioxide in Libya in (2017) and the percentage of these emissions from the total world emissions. Figure 8 shows the annual CO_2 (ton/year) emitted by sectors and the share of each sector in total CO_2 emission and note that the largest proportion of power plants sector (2017).

Table 2. CO_2 Emissions in Libya (2017) [16].

Value	Metric
64.6 million tonnes	Carbon dioxide emissions
0.22%	Emissions share of world total
9.7 ton/year/capita	CO_2 emissions per capita

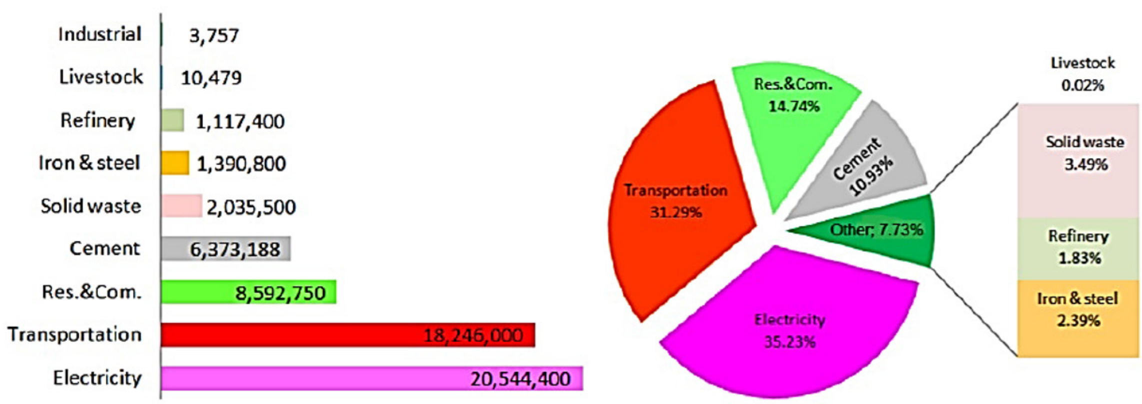

Figure 8. Breakdown CO_2 emission by sectors, (ton/year) [16].

3.2. Libya and United Nations Framework Convention for Climate Change (UNFCCC)

Only countries that have ratified the KP and have established a DNA are eligible to participate in a CDM project. Table 3 shows the relation between Libya and UNFCCC.

Table 3. The relation between Libya and UNFCCC [17].

Libya and UNFCCC	
Ratification of the UNFCCC	June 14th 1999 As non –Annex I
Ratification of Kyoto Protocol	August 24th 2006
Establishment of Designated National Authority (DNA)	2010 [18]

3.3. Prospects CDM in Wind Farms in Libya

Table 4 shows CDM opportunities for wind farms proposed in Libya.

Table 4. Mid-term plan of wind farms in Libya (2010-2020) [17].

Mid-term plan of wind farms in Libya (2010-2020)			
Wind farm	**Capacity (MW)**	**Expected emission reduction CO_2/year (ton)**	**Expected revenues** (US $/year)
Dernah wind farm (I&II)	120	336,384	3,363,840
Magroun wind farm (I&II)	240	672,768	6,727,680
Western wind farms	250	613,200	6,132,000
Southern wind farms	320	784,896	7,848,960
Baida wind farm	70	171,696	1,716,960
Total	**1000**	**2,578,944**	**25,789,440**

<u>All calculations at:</u> Emission factor=0.8 tonCO_2/MWh and CO_2 Price 10 US $/ton CO_2.

4. Methodology

The CDM requires the application of a baseline and monitoring methodology in order to determine the amount of CERs generated by a mitigation CDM project activity in a host country [19]. Methodologies typically pertain to methodological tools that focus on particular aspects of project activities, such as the calculation of GHG emissions from specific sources. After project participants have chosen a suitable approved methodology, they implement it in their project activity and create a Project Design Document (PDD). This marks the initial stage of the CDM project cycle, Figure 9. shows the CDM project cycle. The methodology includes guidelines for the fundamental components of a PDD, such as demonstrating additionality, establishing the baseline scenario, estimating emission reductions or net removals, and devising a monitoring plan, Table 5. shows required content of Project Design Document.

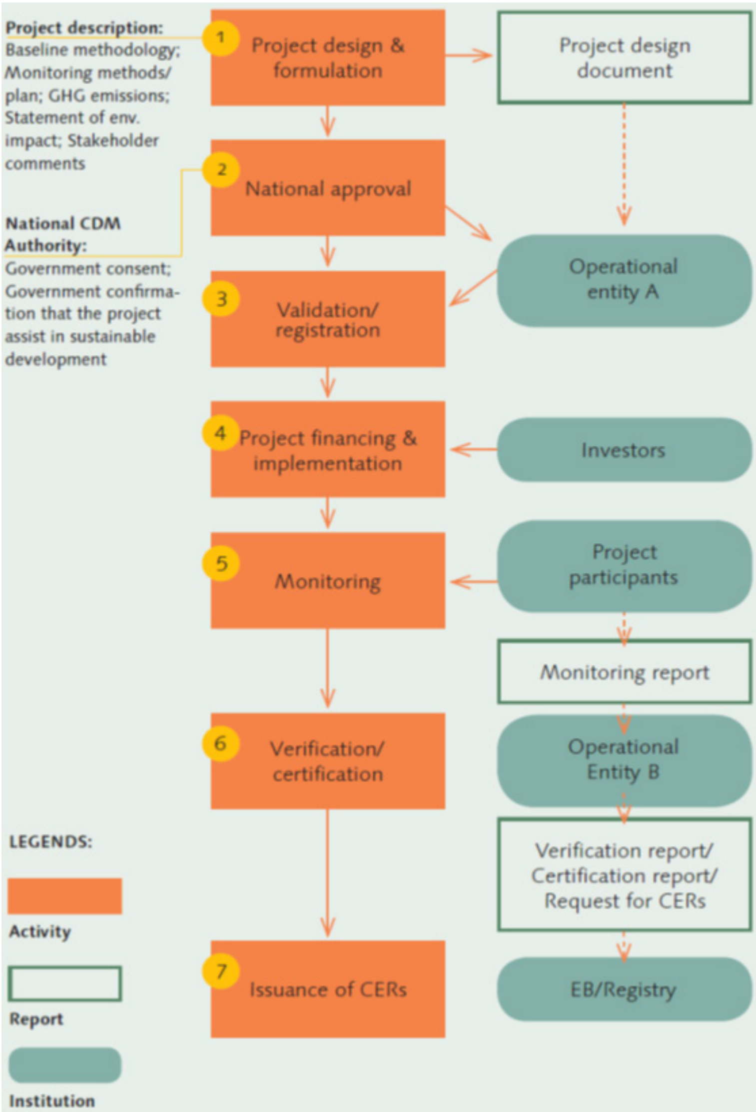

Figure 9. The CDM project cycle.[20].

Table 5. Required content of Project Design Document (PDD) [20].

A	General description of project activity
B	Application of a baseline and monitoring methodology
C	Duration of the project activity/crediting period
D	Environmental impacts
E	Stakeholder comments
Annex 1	Contact information on participants in the project activity
Annex 2	Information regarding public funding
Annex 3	Baseline information
Annex 4	Monitoring information

4.1. Method of CDM Obtain

In this study used a suitable CDM methodology for large-scale CDM project activities, Grid electricity, AM0019 (Renewable energy projects replacing part of the electricity production of one single fossil fuel fired power plant that stands alone or supplies to a grid).

4.1.1. CDM Methodology AM0019

It includes:

- Baseline Scenario:

A specific fossil fuel plant generates electricity that is supplied to the grid (figure 10). In this study, Dernah Steam Power Plant is the baseline project.

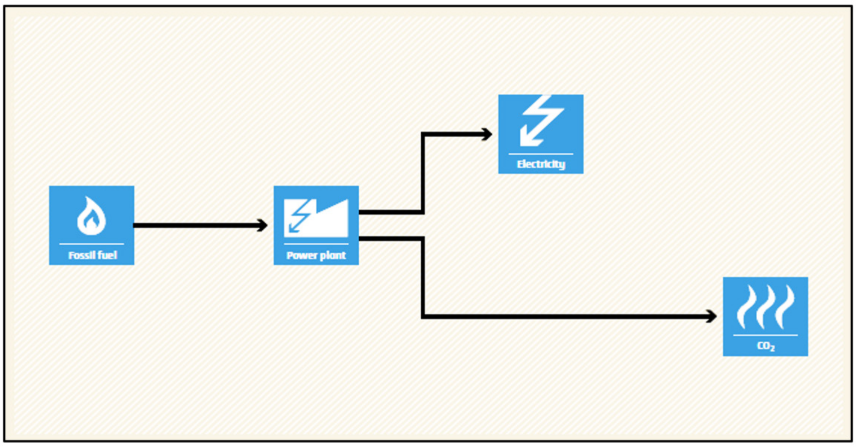

Figure 10. Baseline Scenario of CDM Methodology AM0019 [19].

- Project Scenario:

A renewable energy plant partially or completely displaces the electricity that is generated by the specific fossil fuel power plant (figure 11). In this study, Dernah wind farm (I) is the renewable energy plant project.

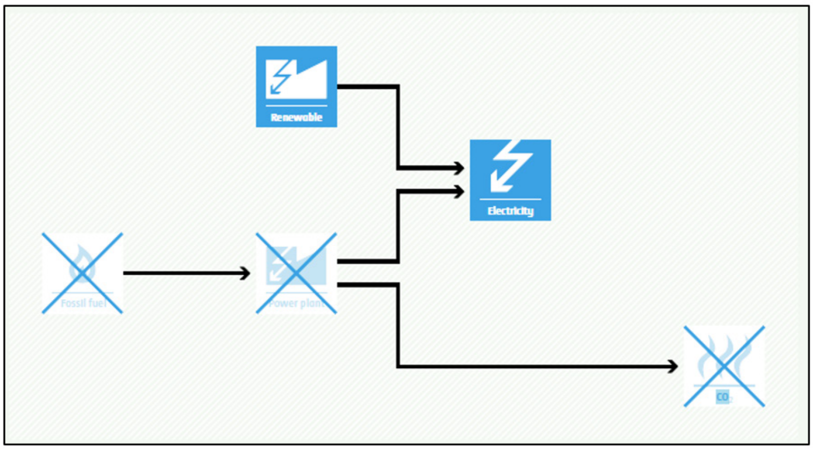

Figure 11. Project Scenario of CDM Methodology AM0019 [19].

- Important parameters:

At validation:

• Carbon emission factor of the baseline power plant.

At Monitored:

• Quantity of electricity supplied to the grid by the project [19,21].

4.1.2. Tool to Calculate Project or Leakage CO_2 Emissions from Fossil Fuel Combustion

In this study, the appropriate tool (TOOL-03-V3) attached to the methodology was used, this tool provides procedures to calculate project and/or leakage CO_2 emissions from the combustion of fossil fuels (The date of entry into force is the date of the publication of the EB 96 meeting report on 22 Sep. 2017), It can be used in cases where CO_2 emissions from fossil fuel combustion are calculated based on the quantity of fuel combusted and its properties. This tool is required by methodologies whenever fossil fuel combustion is relevant in the project scenario or leakage [19,22].

4.1.3. Assumptions, limitations and sources of uncertainties

1- This study analyzes only the Dernah (I) wind farm located in Libya as a hypothetical project implemented under the Clean Development Mechanism.
2- A wind farm (Dernah (I)) of 61.05 MW has been put into construction process by M.TORRES Spanish Company.
3-The wind turbine model is M.TORESS (TWT 1.65/82).
4-The estimated net energy output from the wind farm is 226715 MWh/year.
5- Dernah Steam Power Plant is the baseline project.
6- Dernah wind farm (I) is the renewable energy plant project partially or completely displaces the electricity that is generated by the specific fossil fuel power plant.
7- Typical project in which generating electricity from emission-free renewable energy sources (considering few during the construction, operation (Transportation, maintenance) and dismantling phase) such as a wind project. 8- Important conditions under which the methodology used in this study is applied;
• The identified baseline plant is able to meet any possible increase of energy demand that occurs during the crediting period.
• Three years of historical data is required for the calculation of emissions reductions. In this study, the data were fixed because the Dernah wind farm is a proposed farm that has not been implemented, this is considered one of the main limitations of this study.
9- Use the appropriate tool (TOOL-03-V3) attached to the methodology AM0019.
10- Availability loss (3%) and electrical loss (3%) estimates are applied while computing the net energy production of every turbine, as well as an adaptation factor caused by the uncertainty on the wind flow model, the wind shear estimates and the lack of more years of data [8].

4.1.4. Project boundary

The boundaries of this study conform with the project boundary according to CDM methodology AM0019. Figure 12 shows project boundary according of CDM methodology AM0019 and figure 13 presents the current delivery system boundary for a single project that will be displaced by the proposed project activity.

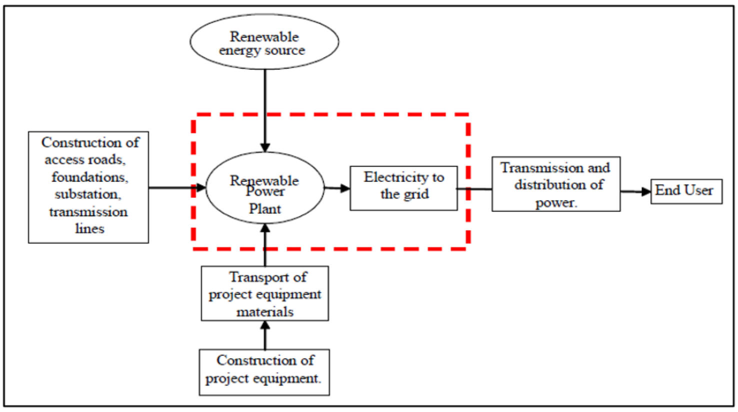

Figure 12. Project boundary according of CDM methodology AM0019 [23].

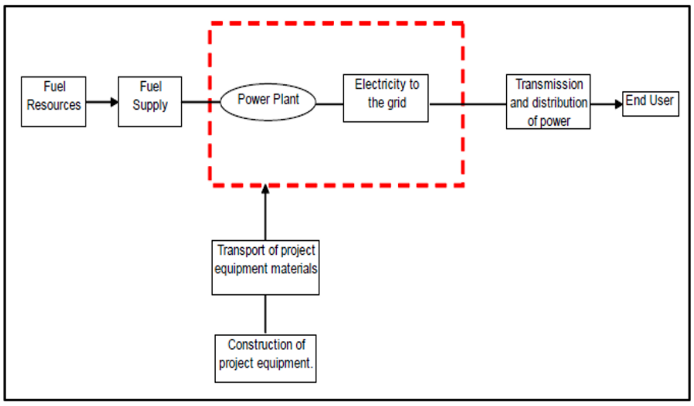

Figure 13. The current delivery system boundary for a single project that will be displaced by the proposed project activity [23].

4.2. Analysis of CDM for Dernah Wind Farm (I) Project (Libya)

In order for a carbon-reduction project to earn carbon credits, it must prove that the reductions in emissions or removals of carbon dioxide are genuine, quantifiable, long-lasting, extra, verified by a third party, and distinct [24].

4.2.1. Baseline methodology procedure

The emission reduction ER_y by the project activity during a given year y is the difference between baseline (Dernah steam power plant) emissions (BE_y), project (Dernah wind farm (I)) emissions (PE_y) and emissions due to leakage (L_y), as follows [22-24]:

$$ER_y = BE_y - PE_y - L_y \quad \text{.................. (1)}$$

-Energy production (The electricity supplied by the project activity (Dernah wind farm (I)) to the grid) estimate has been computed with two programs; WASP and WindFarmer [8]. The estimated energy production from Dernah Wind Farm (I) is 226715 MWh/year [8].
- The baseline (Dernah steam power plant) emissions CO_2 from fossil fuel combustion in process j are calculated based on the quantity of fuels combusted and the CO_2 emission rate (coefficient) of those fuels, as follows [22]:

$$BE_{FC_{j,y}} = \Sigma_i \, FC_{i,j,y} \, X \, COEF_{i,y} \quad \text{.................. (2)}$$

Where:
$BE_{FC_{j,y}}$:
is the CO_2 emissions from fossil fuel combustion in process j during the year y (tCO_2/year).
$FC_{i,j,y}$:
is the quantity of fuel type i combusted in process j during the year y (mass or volume unit/year).
$BE_{FC_{j,y}}$:
is the CO_2 emission rate(coefficient) of fuel type i in year y (tCO_2/mass or volume unit).
i : the fuel types combusted in process j during the year y.
-Dernah steam power plant is using heavy fuel oil (HFO), as presented in table 6.
-The specific gravity and heating value is shown in table 7.

Table 6. Steam power plants in Libyan [25].

Substation name	Fuel	No. of units	Unit capacity (MW)	Total capacity (MW)
Khoms	Heavy oil/Gas	4	120	480
Tripoli West	Heavy oil	5	65	325
		2	120	240
Dernah	Heavy oil	2	65	130
Tobruk	Heavy oil	2	65	130

Table 7. The specific gravity and heating value of heavy fuel oil [26].

Type of fuel	Heating value	Specific gravity
Heavy fuel oil (HFO)	10640 kcal/kg	0.922 kg/L

-The emission rates of NO_x ,SO_2 and CO_2 were calculated according to the procedures and guidelines followed by international firms such as the Intergovernmental Panel on Climate Change (IPCC), UNFCCC considering the chemical analysis of the fuels ,and oxidation factor of 0.99 for HFO and 0.995 for NG recommended by IPCC. The NO_x ,SO_2 and CO_2 emissions are presented in table 8 [26,27].

Table 8. The emission rate of heavy fuel oil [26].

Type of fuel	Emission rate (ton/kg $_{fuel}$) $\times 10^{-3}$		
	NO_x Emission	SO_2 Emission	CO_2 Emission
Heavy fuel oil (HFO)	0.005640	0.04	3.17

Table 9. Fuel (HFO) consumption rate and energy production of Dernah steam power plant [29].

Metric	Dernah Steam Power Plant
Energy production MWh/year	641802
Amount of fuel consumed (m^3)	242613
Average fuel consumption (m^3/MWh)	0.378

Therefore, the amount of fuel consumption per year ($FC_{i,j,y}$) can be calculated from eq. (3), knowing the energy produced by the wind farm and the average fuel consumption in table (9).

5. Results and discussions

The amount of fuel consumption per year ($FC_{i,j,y}$) was estimated using equation (3) as 85,698.27 m3 per year.

The fossil fuel combustion in process j ($FC_{i,j,y}$) can be convert from m3/year to kg $_{fuel}$/year (85,698.27m^3/year ×922 kg_{fuel}/m^3) 79,013,804.94 kg_{fuel}/year.

The atmospheric emissions from fossil fuel combustion due to Dernah steam power plant during the year compared to Dernah wind farm (I) was calculated using Eq. (2) as 250,473.762 $tCO_{2\,e}$/year, 3,160.6 t SO_2/year and 445.64 t NO_x /year respectively.

- SO_2 is not considered as greenhouse gases because they don't remain in large amounts in atmosphere since they are converted into sulfuric acid [30,31].
- Carbon credits are always expressed in term of carbon dioxide equivalence ($CO_{2\,e}$). From table 10 below Global Warming Potential (GWP) of 1 tonne of nitrous oxide=298 $tCO_{2\,e}$.

Table 10. Global Warming Potential [32].

Greenhouse Gas (GHG)	Global Warming Potential (GWP)
Carbon dioxide	1
Methane	25
Nitrous oxide	298

So, the nitrous oxide and sulfur oxide can be converted to carbon dioxide equivalence ($CO_{2\,e}$), using eq.(2) as: 132,800.7 $tCO_{2\,e}$/year and 383,274.5 $tCO_{2\,e}$/year respectively.

-The project emission based on wind energy will be zero (PE_y=0) [24]
-The emissions due to leakage (L_y); A possible source of leakage might be that the emissions during the construction, commissioning and decommissioning phases or recycling the components of the proposed project activity turn out to be significant [23]. Total emissions with recycling of Dernah Wind Farm (*I*) Project is (L_y) is 21,072.684 $tCO_{2\,e}$ [28].
Therefore, The emission reduction (ER_y) by the project activity during a given year 1y from eq. (1) is estimated as 362,201.82 $tCO_{2\,e}$/year.
The amount of emissions that can be prevented by using clean technology can be converted into carbon reduction certificates equivalent to the amount of energy produced and achieve economic returns, as prices per metric ton of carbon dioxide to the World Bank for emissions trading and through the carbon market, which reached 88.58 €/tCO_2 average for the three months (Jun, Jul, Aug) of 2023 [33] as follows:
Carbon Saving by using CDM would be 32, 083,837.2 €/year or168,789,859 LD/year with the rate of exchange of (5.2609) LD/€ .
From this it is possible to find the amount of the emissions of carbon dioxide that can be avoided or prevented along the life span of the proposed farm, which is estimated at about 20 years old (table 1).
The total CERs generated is determined by the selected crediting period. The Marrakesh Accord of 2001(includes the guidelines for implementing the CDM) specifies two options for project developers: 7 years with twice the option of renewal (totaling 21 years) or, 10 years without renewal [10]. In many cases project participants would prefer a longer crediting period to the 10 year option without a renewal, this means that participants in the project can choose to have a longer crediting period of up to 30 years or three consecutive periods of 10 years each [7].
The total CERs to the 10 year ($CERs_{10y}$) was estimated as 1,687,898,590 LD, (320,838,371.8 €), for the first ten years of the age of Dernah Wind Farm and for 20 years ($CERs_{20y}$) or during the entire life of the Wind Farm as 3,375,797,180 LD, (641,676,743.5 €).
All the calculations are attached in the Appendix.

6. Conclusion and Recommendations

Clean Development Mechanism projects provide a platform to align climate change policies with Sustainable Development (SD) policies that address key national development priorities. By assessing potential CDM projects against selected SD criteria encompassing economic, social, and environmental aspects deemed significant by host countries, these dual policy objectives can be effectively supported. Host countries have the flexibility to choose from a wide range of indicators, such as financial and technology transfer, income generation, employment opportunities, local environmental effects, health, social progress, and equity. The results of CDM analysis are; CO_2 reductions= 362,201.82 $tCO_{2\,e}$/year and $CERs_{10y}$ is 1,687,898,590 LD (320,838,371.8 €) for the first ten years likewise $CERs_{20y}$ is 3,375,797,180 LD (641,676,743.5 €) during the entire life of the proposed wind farm. Based on this , it is concludes that the project will be very cost-effective, this will lead to lower electricity prices for consumers and higher profits for the project owners, therefore registering wind energy projects as CDM projects and earning CERs is the most practical way to promote wind energy. The inclusion of carbon trading revenue can greatly enhance the economic competitiveness and investment appeal of wind power projects, playing a vital role in promoting and facilitating investments in such projects .The findings of this study could be valuable for policy makers and project developers who are interested in CDM wind projects, and implementing this study to all Dernah wind farm construction stages after the completion of the second stage designs for the project (Dernah wind farm (II)). The monitoring plan takes place three years after the project is fully implemented, at that time the PDD will be prepared. Since the project is proposed, this step has not been implemented; this is considered a limitation in this study.

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Appendix

Research's calculations

Convert from m^3/year to kg $_{fuel}$/year →85,698.27m^3/year ×922 kg $_{fuel}$/m^3= 79,013,804.94kg $_{fuel}$/year
Air emissions calculations:
$BE(CO_2)_{,y}$=79,013,804.94 kg fuel/year × 3.17 ×10-3 $tCO_{2\,e}$/kg fue = 250,473.762 $tCO_{2\,e}$/year.
$BE(SO_2)_{,y}$ = 79,013,804.94 kg fuel/year × 0.04×10-3 t SO_2/kg fuel = 3,160.6 t SO_2/year.
$BE(NO_x)_{,y}$ = 79,013,804.94 kg fuel/year × 0.005640×10-3 t NO_x /kg fuel = 445.64 t NO_x /year.
$BE(NO_x)_{,y}$ =445.64 t NO_x /year × 298 =132,800.7 $tCO_{2\,e}$/year (from eq.(2))
$BE_{FC,i,y} = BE_{,y}$ =250,473.762 $tCO_{2\,e}$/year +132,800.7 $tCO_{2\,e}$/year = 383,274.5 $tCO_{2\,e}$/year.
The emission reduction ER_y 362,201.82= 21,072.684 – 0 – 383,274.5 = $tCO_{2\,e}$/year .
Carbon Saving by using CDM: 88.58 €/$tCO_{2\,e}$ × 362,201.82 $tCO_{2\,e}$/year =32,083,837.2 €/year =32, 083,837.2 €/year ×5.2609 LD/€= 168,789,859 LD/year.
The Certified Emission Reductions during 10 years is $CERs_{10y}$=168,789,859 LD/year × 10 year =1,687,898,590 LD, (320,838,371.8 €). For the first ten years of the age of Dernah Wind Farm (I).
The Certified Emission Reductions during the lifespan is $CERs_{20y}$=168,789,859 LD/year × 20 year =3,375,797,180 LD, (641,676,743.5 €). During the entire life of Dernah Wind Farm (I).