LOS AZUFRES GEOTHERMAL FIELD AS A PROTOTYPE OF MDL ON THE ELECTRICAL SECTOR

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RESUMEN.

La geotérmica es una forma limpia de producción eléctrica, sin embargo, dentro de su proceso, genera emisiones importantes de gases de efecto invernadero (gei). En México, el campo geotérmico Los Azufres produce anualmente 14 millones de toneladas (torres, 2007), de vapor endógeno, de los cuales 3% (420.000 tco2) aproximadamente son rechazadas a la atmósfera. Si estos gases se transforman en "certificados de reducción de emisiones" (cer) en el mercado de carbono, no sólo contribuiría a la atmósfera, también podría obtener un beneficio financiero adicional para sus ventas.

Este documento quiere demostrar que el campo de Los Azufres geotérmica como parte de la industria eléctrica renovable en México es un excelente candidato para reducir las emisiones y, con ello, participar en el mercado internacional del carbono y genera beneficios financieros positivos para la compañía, a través de un proyecto que establece la reducción de sus emisiones de gei presente a la atmósfera.

Palabras clave: Reducción de emisiones (RE), Sistema Nacional Interconectado (SIN), Comisión Federal de Electricidad (CFE), campo geotérmico Los Azufres (LAGF).

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ABSTRACT.

Geothermic is a clean electrical production form, nevertheless within its process, it generates important emissions of Greenhouse Gases (GHG). In Mexico, Los Azufres Geothermal Field annually produces 14 million tons (Torres, 2007) of endogenous steam, from which 3% (420,000 tCO2) approximately are rejected to the atmosphere. If these gases were transformed into “Certificates of Reduction of Emissions” (CER´s) in the Carbon market, it would not only contribute to the atmosphere, it also could obtain an additional financial benefit to its sales.

This document wants to demonstrate that Los Azufres geothermal field as part of electrical renewable industry in Mexico is an excellent candidate to reduce emissions and with it, take part on the international carbon market and generates positive financial benefits for the company, through a project that establishes the reduction of its present GEI emissions to the atmosphere.

Keywords: Reduccion emission (RE), Interconectected National System (SIN), Comision Federal de Electricidad (CFE), Los Azufres Geothermal Field (LAGF).

JEL Classification: L1, L16, Q4, Q42.

1. INTRODUCTION.

The electrical sector is one of the most important industries of the nations, because it represents the basic source to economic development of such. Consequently, the flood and fast industrialization have caused the necessity to increase the electrical services to cover the demand; therefore, this increase has been caused the increase of polluting emissions to the atmosphere of GHG. In fact, now this sector is considered one of the most important GHG transmitters per year (Stern, 2007).

Mexican electrical system is conform by three entities: Comisión Federal de Electricidad (CFE), Luz y Fuerza del Centro (LyFC) and a new participating calls External Power Producers (EPP) (producers external to the CFE’s administrative organization but selling electricity to CFE under Power Purchase Agreements, self-suppliers, cogeneration and small-scale generation.

The generation of electrical Mexican energy emits approximately 160, 796 GgCO2e (Luegue, 2002), which if we transformed them into Certificates of Reduction of Emission; this one could obtain a probable entrance of around 800 million of Euros, per year. Nevertheless, CFE as a mayor generator of power electricity of the 177 power plants conform the company, only one (web.worldbank.org) is participating within the Carbon market and it is obtaining the financial benefits that commerce of the emission reductions represents. It means the 176 remaining power plants are letting gain these benefits to not participate on the international trade of credits carbon.

Nevertheless, there are some investigation lines that affirm the carbon market generally does not represent any financial benefit for the producers of the diverse sectors in the developing countries. For this reason, the main task of this work is to demonstrate that, although it is not the main objective of the market of carbon, the participation of the companies in this one, it could represent an important plus entrance, which could be used in the different necessities for it.

Comisión Federal de Electricidad (CFE) like main generator, and only institution in Mexico in charge of transmission, distribution and sale of electrical energy, represents one of the best options to establish a proposal of reduction of emissions GEI, using in this case the power plant of the Geothermal field Los Azufres, in Michoacán México.

2. GEOTHERMIC IN MEXICO AND THE BENEFIT IN LOS AZUFRES GEOTHERMAL FIELDS.

The generation of electrical energy is carried out by diverse sources: gas, coal, etc., (fossils combustible) and other alternating sources like geothermic steam, wind and solar energy, among others. The source more used in Mexico is by combustion of fossil combustor, in such more than 60% of the total generation is produced by thermoelectric power plant (CFE, 2009), it means the greater producer of electrical Mexican energy is generating too one of the most important source of polluting emissions to the atmosphere. But, it isn´t the unique GHG transmitter in this sector, there are also some renewable sources that generate emissions in its process. One of them is the geothermic one.

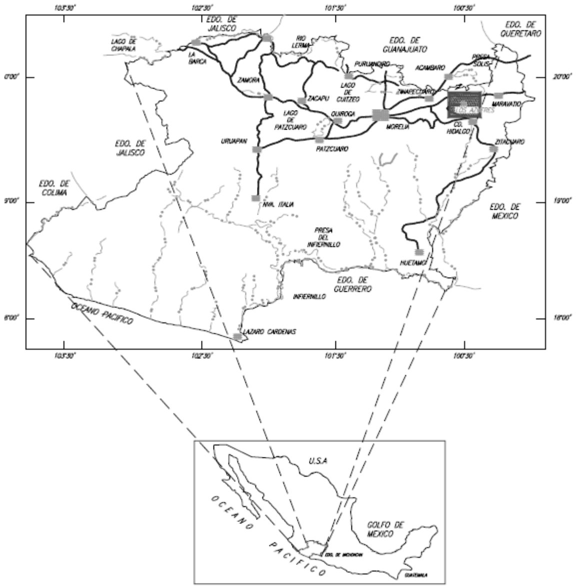
At present, there are four geothermal fields in operation in México: Cerro Prieto, Los Azufres, Los Humeros and Las Tres Vírgenes. These altogether produce around 70, 22 million tons of endogenous steam per year (Torres, 2007), which if we took this data base as example, 3% of it is unloading as a gas of remainder to the atmosphere, it means around 2, 1 million tCO2e, which a price 7 Euros (price of the Verification Emission Reductions agreed for La Venta II) would be equivalent to almost 15 million Euros per year. It means significant extra incomes to the company from it electrical sales.

Taking in account last data, the CFE geothermic even it has an important potential of GHG reductions emissions, but it haven´t any project CDM register in UNFCCC, for that, we taking as reference Los Azufres geothermal field, second endogenous steam producer in Mexico, thus second mayor emissary of GHG.

2.1 Los Azufres geothermal field (LAGF).

It is located in San Andrés Mountain, eastern limit to Michoacán State, 80 km East to Morelia City and 250 km to Mexico City (Fig. 1).

Figure 1: Localization of the LAGF, México.



Source: Proyecto Azufres III, CFE, 2007.

LAGF as part of CFE began its commercial exploitation in 1982, using as renewal source of generation endogenous steam. This field is divided in two zones: south and north, because the geologic and geochemistry characteristics, from production and deposits differ in some aspects. South zone presents highest temperatures and greater production of the field, also the deposit is briefer than in North. In both zones the geologic structures have good permeability; the chemical composition of the fluids is alkali-chloride waters (NaCl) of neutral pH type, although the chemical content of solutes is greater in wells of the South zone than in North one. At present its capacity installed is 188 MW, with an infrastructure of 80 wells with a depth between 600 and 3500 m.s, of which 42 are producing wells, 6 injectors, 4 monitoring, 21 nonproducing, 5 closed and 2 exploratory ones. It account with fourteen distributed units of electrical generation of the following way: 5 in the South zone fed by 18 producing wells, 2 units of binary cycle using residual brine and 7 units in the North zone fed by 22 wells. Of these, seven units are to back pressure with capacity of 5 MW each one, and with specific consumption average of 13.7 t/h-MW. Three are located in South zone and four in the North zone.

LAGF produces 14 million tons of endogenous steam, of which approximately 6.31% average are emanated to the atmosphere, this is equivalent to 883.400 tCO2e/yr. This emission presents a composition average of 97% Carbon Dioxide (CO2), hydrogen sulfide (H2S), Ammonium (NH4) and others, therefore this emission shows a good potential of reduction GHG. Thus, almost 857,000 tons transformed into certificates of reduction of emissions, could be an equivalent to 5,998,286 •/yr (7• / tCO2 reduced). Moreover, this benefit not only would be reflected in the economic aspect; in noneconomic aspects, the reduction of GHG emissions would have positive externalities contributing with the society in human health, agriculture, nourishing resources.

In conclusion, this field represented the second more important steam producer in México, thus, it could consider one of the most important prototypes of transformation of its GHG emissions, in credits tradable in international Carbon market, and this way not only to obtain the economic benefits from this commerce, in addition it globally contributes to sustainable development of the country and decontamination of environment.

2.2 Project of reduction of GHG emissions in LAGF.

The project consists in replacement 7 back pressure units of low efficiency by two condensation units of less consumption. This action will reduce specific consumption from 13.7 to 7.6 t/h-MW from north zone and to 8.4 t/h-MW from south zone, thus they will reduce the amount of endogenous steam tonnage used to generation electricity in 55% and 61% respectively, and it will be able to increase the amount of electricity delivered from 35 MW to 75 MW toward the grid with the same steam extracted, plus additional 110 t/h of steam, it means LAGF could increase 40 MW drilling only 2 or 3 new wells.

2.3. Estimation of emission reduction (ER) in LAGF.

To estimate the ER produced in LAGF project, will be use the methodology approved and valid by UNFCCC, calls: "Consolidated baseline methodology for grid-connected electricity generation from renewable sources", version 9 (ACM0002).

2.3.1. Baseline methodology.

The project boundary is the interconnected national system (SIN) for its abbreviation in Spanish, in fact that the electrical power supply by the project will be connected to the grid.

For this investigation the procedure to follow the baseline methodology will be:

1. Select an operating margin (OM) method and calculate it;
2. Identify the power units to be included in the build margin (BM) and calculate it; and
3. Calculate the combine margin (CM emission factor).

This methodological tool determines the CO2 emission factor for the displacement of electricity generated by power plants in an electricity system, by calculating the operating margin (OM) and build margin (BM) as well as the combined margin. (CM). The OM refers to a cohort of power plants that reflect the existing power plants whose electricity generation would be affected by the proposed CDM project activity. BM refers to a cohort of power units that reflect the type of power units whose construction would be affected by the proposed CDM project activity, and CM calculates baseline emissions for electricity project activity from the grid.

The project compliment with the following conditions established in methodology:

- The project activity is the replacement of geothermic power plants, which will be supply electric power to the interconnected national Mexican system;
- The project activity doesn´t involve switching from fossil fuels to renewable energy sources at the site of it;
- And the electrical grid is clearly identified and the historical data of three years is available.

2.3.2. Identification of the baseline scenario.

According the methodology this project concurs with the fact that "Electricity delivered to the grid by the project activity would have otherwise been generated by the operation of grid-connected power plants and by the addition of new generation sources", as reflected in the combined margin (CM) calculations described in the "Tool to calculate the emission factor for an electricity system" (EB 35/Annex 12/V01.1).

Following the methodology, the emission factor of baseline CM will be calculated as a combination of the operating margin (OM) and the building margin (BM), with an average participation of 50% and 50% respectively.. All coefficients are express in CO2/MWh. And the project boundary is the interconnected national system (SIN).

2.3.3. Calculate of the OM emission factor.

The calculation of the operating margin (OM) emission factor is based on one of the following methods:

(a) Simple OM, or
(b) Simple adjusted OM, or
(c) Dispatch data analysis OM, or
(d) Average OM.

Where, the selected method to calculate the OM emission factor to LAGF project is taking the Simple OM one, on the fact that, this one is calculated as the generation-weighted average CO2 emissions per net unit electricity generation (tCO2/MWh) of all generating power plants serving the system (SIN), not including low-cost / must-run power plants / units.

For the first crediting period, the calculate OM emission factor will be done using the *ex-ante option*, because the Mexican SIN is considerate highly complex, in the fact there are many different fuel types, the SIN is shaped by 177 per plants/units, etc., in this way, results so inconvenient to calculate every year the OM factor.

According last paragraph, we will take the value of Simple OM ex – ante emission factor calculation from La Venta II project (PDD from http://cdm.unfccc.int/Projects/ DB/AENOR1168204945.7/view.

The equation to calculate the Simple OM ex-ante for the first period of crediting is:

$$EF_{OMsimple,y} = \frac{\sum_{i,j} EG_{i,j,y} * COEF_{i,j}}{\sum_{j} EG_{j,y}} \qquad (1)$$

Where:

$EF_{OMsimple,}$ = Simple operating margin CO2 emission factor in year y (tCO2/MWh)

$EG_{m,y}$ = Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (MWh)

$COEF_{y}$ = Coefficient of CO_2 emission factor per type of fossil fuel i per power unit *m* in year *y*. Which is conform by the following data:

$EF_{CO2,m,i,y}$ = Average CO_2 emission factor of fuel type *i* used in power unit *m* in year *y* (tCO_2/GJ)

NVC = Net calorific value (energy content) of fossil fuel type I in year y (GJ)

Conversion efficiencies of power units were taken from the official internal reports of CFE. With this information there was obtained the weighted average of net efficiencies conversion for every fuel.

Table 1. Simple OM ex-ante to LAGF.

Tech. Part	Tecnology	MWh 2005-2003	NEC (%)	tCO2e
15%	Coal	29,664,595	33.05	29,960,588
31%	Natural Gas Combined Cycle	60,513,582	45.85	25,134,510
0%	Wind	4,957	0.00	
1%	Geothermal	1,503,031	0.00	
12%	Hydro	24,146,988	0.00	
5%	Nuclear	10,166,783	0.00	
5%	Natural Gas Simple Cycle	9,651,782	28.96	6,346,893
1%	Diesel	1,783,210	26.10	1,803,753
0.3	Residual Fuel Oil	58,554,996	33.00	48,930,938
	Total	195,989,924		
	Low Cost/Must Run	35,821,759		
	Total Low Cost/Must Run	160,168,165		112,176,682
	Imports	7427.2		
	OM=	**0.700368154**		

Source: PDD La Venta II from http://cdm.unfccc.int/ Projects/DB/ AENOR1168204945.7/view

Getting an OM result of 0.700368, the following step is the estimate of BM emission factor.

2.3.4. Calculate the build margin emission factor (BM).

The BM emissions factor is the generation-weighted average emission factor (tCO2/MWh) of all power units m during the most recent year y for which power generation data is available, calculated as follows:

$$EF_{grid,BM,y} = \frac{\sum_{m} F_{i,m,y}\, COEF_{i,m}}{\sum_{m} EG_{m,y}} \qquad (2)$$

CO2 emission factor of each power unit m must be calculated by one of the follow options:

- Ex-ante option: using for 5 most recent historical year for which power generation data is available, or the later capacity additions to conform 20% of system generation. Must be to be used the data of bigger annual generation;

- Ex-post option: using for the first crediting period ex-ante option and to the following one the ex-post coefficient.

At the same way of OM, BM emission factor will be done using ex – ante option by the complexity of the SIN. Then, the value will be of the La Venta II, too. In this way the BM emission factor is showed to follow:

Table 2. Build Margin ex-ante to LAGF.

Tech. Part	Tecnology	MWh 2005-2003	NEC (%)	TJ	tCO2e
0%	Coal	0	33.05		
95%	Natural Gas Combined Cycle	40,963,715	45.85	321,628	17,014,410
0%	Wind	0	0.00		
2%	Geothermal	932,226	0.00		
2%	Hydro	717,068	0.00		
0%	Nuclear	0	0.00		
1%	Natural Gas Simple Cycle	401,218	28.96	4,987	263,836
0%	Diesel	11,431	26.10	158	11,562
0%	Imports	143.94	0.00		
0%	Residual Fuel Oil	0	33.00		
	Total	43,025,802			17,289,808
	BM=	**0.401847432**			

Source: PDD La Venta II from http://cdm.unfccc.int/ Projects/DB/ AENOR1168204945.7/view

Getting a BM result of 0.401847, we proceed to estimate the combined margin (CM) emissions factor.

2.3.5. Combine margin (CM) emissions factor.

The equation to calculate the CM is showed following:

EF grid,CM,y = (EF OM,y * WOM) + (EFBM,y * WBM) (3)

Where:

$EF_{grid,BM,y}$ = Build margin CO_2 emission factor in year *y* (tCO_2/MWh)

$EF_{grid,OM,y}$ = Operating margin CO_2 emission factor in year *y* (tCO_2/MWh)

w_{OM} = Weighting of operating margin emissions factor (%)
w_{BM} = Weighting of build margin emissions factor (%)

According to the methodology WOM=0.5 and WBM=0.5 for first crediting period. In this way, the equation will be the follow:

EF grid,CM,y = (0.70036*0.5) + (0.41085 * 0.5)
= 0.5556 tCO_2/MWh

The calculations were done dividing LAGF in two zones, where, the replacement of 4 units will be carried out in the north zone; and the replacement of the other 3 units will be realized in the south zone of it. In addition the physicochemical properties of each zones is different, thus, the calculations must be done separately.

In this way, the calculation will be done in the follow order:

- Calculate of emissions of CO_2 derivate from the project
- Calculate baseline emissions from electricity supplied by fossil fuel generation and displaced due to the electricity activities
- Calculate of Total Emission reductions

2.3.6. Calculate the emission of CO2 derivate from Los Azufres Project.

For geothermal project activities, the PEy emission will be calculated as follow:

PEy = PESy (4)

Where:

PEy = Project emissions in year y (tCO_2/yr)
PESy = Project emissions of CO_2 release of non-condensable gases from produced steam in year y (tCO_2/yr)

And PESy= WCO2 * M S,y (5)

Where:

WCO2 = Average mass fraction of carbon dioxide in the produced steam (non-dimensional).
Ms,y = Quantity of steam produced during the year *y* (tones); so, we have:

Table 3. PES from LAGF project. North zone.

North zone		
Net generation	50	MW/h
Capacity production power plant (Cpp)	7.6	t/MWh
Steam feed power plant	380	t/h
Non-condensable gases	3	%w
Composition non-condensable gases	97	% CO2
	2	% H2S
	1	% NH4
Dispatch hourly annually (dha)	8760	h/yr
PESn=	**96,868.08**	**t/yr**

Source: Own creation with data provided by GPG of CFE

Table 4. PES from LAGF project. South zone.

South zone		
Net generation	25	MW/h
Capacity production power plant	8.4	t/MWh
Steam feed power plant	210	t/h
Non-condensable gases	10	%w
Composition non-condensable gases	97	% CO2
	2	% H2S
	1	% NH4
Dispatch hourly annually	8760	h/yr
PESs=	**178,441.20**	**t/yr**

Source: Own creation with data provided by GPG of CFE

In this way:
North zone PE LAGF = 96,868.1 t/yr
South zone PE LAGF =178,441.2 t/yr

2.3.7. Calculate of emissions of CO2 from fossil fuel displace due to the LAGF activity.

LAGF project consist to change 7 pressure power plants for 2 new condensate power plants, then, the equation will be express as:

BEy = EGy * CM (6)

Where:

BEy = Baseline emissions in year y (tCO_2/yr)
EGy = Electricity supplied by the project activity to the grid MWh)
CM = Combined margin CO_2 emission factor for grid connected power generation per year.
And, EGy = (Generation capacity* Dispatch hourly annually)

North zone:
BEy = (50 MW/h) * (8760 h/yr) * (0.5556)
BEy = 243,353 tCO_2/yr

South zone:
BEy = (25 MW/h) * (8760 h/yr) * (0.5556)
BEy = 121,676 tCO_2/yr

From these values, we will discount the total fugitive emissions estimation.

EFugitive = (Steam feed power plants) * (Dha) * (%g) * (%CO2) (8)

Where:

SFpp = Steam feed of power plant/unit (t/MWh)

Dha = Dispatch hourly annually (h/yr)
%g = Non condensable gases (%)
%CO2 = CO2 percent in the composition of non- condensable gases

Then, we have:
North zone: EF CO2 = (274 * 8760 * 0.03 * 0.97)
= 69,847 tCO2/yr

South zone: EF CO2= (206 * 8760 * 0.10 * 0.97)
= 175,042 tCO2/yr

Then, taking in account there is already discharged a fugitive emission from the actual activities (7 power plants emissions), so, we will discount the EF CO2 emission to the LAGF project emission, so:

Total EFCO2 = PEy - EFCO2y (9)

North zone:
Total EFCO2 = 96,868 – 69,847 **= 27,012 tCO2/yr**

South zone:
Total EFCO2 = 178,441 – 175, 042 **= 3399 tCO2/yr**

This information shows us that exists an important emission of CO2 which is been rejecting to the atmosphere, reason for which the fugitive final emission shows very small values, situation that it observes with major interest in the south zone in comparison of the north zone, even though the high levels of gases no condensable emission are already coming out from the atmosphere into three different units.

On both cases, transferring the production to a power plant more efficient, the number of emissions was reduced on 72 % from north zone and 98% on south zone. Which shows a great potential to this project, at least on the first crediting period?

2.3.8. Calculate Emission Reductions (ER).

The equation for Emission reductions is:

ERy= BEy – (PEy – EFCO2y (9)

Where:

ERy	=	Emission reductions in year y (t CO_2e/yr)
BEy	=	Baseline emissions in year y (t CO_2e/yr)
PEy	=	Project emissions in year y (t CO_2/yr)
EFCO2y	=	Total Fugitive emissions in year y (t CO_2/yr)

North Zone:
ERy = 243,353 tCO_2/yr – 27,021 tCO_2/yr

ERy = 216,332 tCO_2/yr

South zone:
ERy = 121,676 tCO_2/yr – 3399 tCO_2/yr

ERy = 118,227 tCO_2/yr

The ER from north and south zones consolidate to Los Azufres Geothermal Field as an important prospectus of reduction emissions project, which, presents a wide volume of tCO_2.

CONCLUSIONS.

North zone with 216,332 tCO_2/yr is a big project of ER, which has almost the double ER than the south one.

South zone reservoir has high volume of incondensable gases (10%), which, in the beginning it could mean an unviable project for no emission reduction, but taking in account that the CO_2 emissions are already coming out from three different power plants (175,042 tCO_2/yr), the result change radically from unviable one to an excellent RE project with a lowest fugitive emission result.

LAGF is an excellent prototype of RE project of low risk, because it could produce high volume of RE (around 334,559 tCO_2/yr) on a secure way, because it from a secure source caused with a reservoir capacity to production and the time life of the new technology guarantee more than 30 years of life.

LAGF represents an excellent prototype of low risk MDL project, since it offers a great production of RE through of a geothermal reservoir which useful life counts at list 30 years. Situation that shows it as an attractive option for those countries or companies with obligations of RE.

Geothermal energy, as part of the governmental policy in Mexico, conforms the base of the national interconnected system, assuring the total consumption of the available production.

In case to establish different times to implement both zone as separated projects, each one represent a good candidate for RE reduction of emission in MDL market.

Los Azufres III could yield economic benefit from the sale of CERs in the international carbon market ranging from •501,839 per year (lowest price estimate •1.5 refereed from Carbon, 2009) to •3,632,590 per year (highest price estimate, •13 refereed from Carbon, 2009). But taking in account that the period of compliment is closer, low risk project, big volume of RE, a middle rank price of •7, it could rise around •2,341,914 per year, and if the period of contract is for 10 years (at list) it could reach •23,419,130.

Taking as example LAGF, the MDL represents to Geothermic an great opportunity to increase not only its financial benefit, it could represent one way to incentive the sustainable development to it industry and in a development country as México.

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