Proceeding World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Carbon Market in Mexican Electrical Sector: Proposal for Los Azufres Geothermal Field, México

Claudia Hernández, Roberto Cadenas, Rubén Molina

ININEE, Universidad Michoacana de San Nicolás de Hidalgo;

Gerencia de Proyectos Geotermoeléctricos, Comisión Federal de Electricidad;

ININEE, Universidad Michoacana de San Nicolás de Hidalgo;

claudia.hernandez04@hotmail.com, roberto.cadenas@cfe.gob.mx , ruben.molinam@gmail.com

Keywords: Clean Development Mechanism (CDM) Geothermal Energy, Emissions Reduction (ER), Comision Federal de Electricidad (CFE), Los Azufres Geothermal Field (LAGF).

ABSTRACT

This paper demonstrates that Los Azufres geothermal field, as a part of the renewable energy industry in Mexico, is a good candidate to reduce CO2 emissions and takes part in the international carbon market by generating positive financial benefits for the company. A new project, named Los Azufres III, will apply for its registration as a Clean Development Mechanism (CDM) project.

1. INTRODUCTION

The electrical sector is one of the most important industries in Mexico and it represents one of the basic sources of economic development. Consequently, the fast industrialization has resulted in the need to increase the electrical services to cover the demand. Consequently, this increase has led to the increase of polluting emissions to the atmosphere as greenhouse gases (GHGs). In fact, this sector is considered one of the most important GHG transmitters per year (Stern, 2007).

The use of geothermal energy is one way to reduce GHG emissions by displacing fossil fuel combustion. Despite the fact that México has been using geothermal energy to produce electricity since more than 30 years ago, and having reached third place in terms of installed capacity worldwide, it is only now that a geothermal project in Mexico is participating in the carbon market.

The idea of getting the first geothermal project to be registered as CDM project led us to present this paper. A new project in Los Azufres geothermal field proposes to undertake a more efficient use of geothermal energy by retiring seven (7) steam turbines of back pressure type and installing two new condensing cycles. This change in design can translate to an increase in net power delivered to the grid and a reduction in the emissions factor.

To estimate the probable benefits that the project could provide, in terms of CO2 emissions reduction and economic resources obtained from the sales of carbon credits through the CDM, the approved methodologies to calculate the volume of emissions reduction are applied, using recent references from previous studies made for another Mexican project.

It is important to point out that there are some opinions claiming that the carbon market generally does not represent significant financial benefit for the producers of renewable energy in developing countries. For this reason, the main task of this paper is to demonstrate that a participation in such a market could enhance the project's profitability. One aspect that makes the Los Azufres III project an exceptional case is the fact that one of the power units will be fed from a geothermal resource with high non-condensable gases (NCGs), estimated at 10% by mass. Thus, the expected project benefits from the Clean Develop Mechanism (CDM) may further be compromised. The answer is provided in the conclusions.

2. LOS AZUFRES GEOTHERMAL FIELD (LAGF)

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

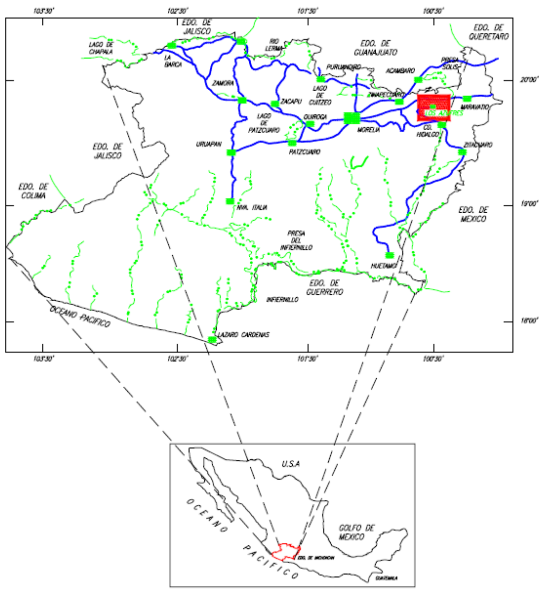

Figure 1: Localization of the LAGF, México.

Source: Proyecto Azufres III, CFE, 2007.

LAGF, as part of Comision Federal de Electricidad (CFE), began its commercial exploitation in 1982, using as renewable source of generation – the indigenous steam. This field is divided in two zones: south and north, as the geological and geochemical characteristics differ in some aspects. The South zone has the higher temperature and greater production between the two (2) fields; also the deposits are briefer than in the 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. At present, the installed capacity is 188 MW, with a total of 80 wells with depth between 600 and 3500 m, from which 42 are producing wells, 6 injectors, 4 monitoring, 21 nonproducing, 5 closed and 2 exploratory ones. LAGF has fourteen (14) electrical generating units distributed as follows:: five (5) in the South zone fed by 18 producing wells, two (2) units of binary cycle using residual brine and seven (7) units in the North zone fed by 22 wells. From these units, seven (7) are back pressure types with a capacity of 5 MW each and with specific steam consumption of 13.7 t/h-MW average. Three (3) are located in South zone and four (4) in the North zone.

3. LOS AZUFRES III PROJECT

The project consists of replacing seven (7) back pressure units of low efficiency with two condensing units of higher efficiency. This action will reduce the specific steam consumption from 13.7 to 7.6 t/MWh for the North zone and up to 8.4 t/MWh for the South zone of the geothermal field. The total output will be increased from 35 MW to 75 MW net using steam that presently are feeding the back pressure units, plus 110 t/h of additional steam that will come from 3 new wells.

3.1 Methodology to Estimate Emissions Reduction (ER)

To estimate the ER produced from Los Azufres III project operations, the methodology approved and validated by UNFCCC: “Consolidated baseline methodology for grid-connected electricity generation from renewable sources”, version 9 (ACM0002), was used.

3.2 Baseline Methodology

Electricity produced by the new geothermal power plants will be delivered to the Mexican national interconnected system.

The procedures followed in determining the baseline methodology are as follows:

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

The methodology determines the CO2 emission factor for the displacement of electricity generated by the power plants in an electricity system by calculating the OM and BM as well as the CM. The OM refers to a combination 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 combination of power units that reflect the type of power units whose construction would be affected by the proposed CDM project activity. The CM calculates baseline emissions for electricity project activity from the grid.

3.3 Identification of the Baseline Scenario

According to the adopted methodology, this project concurs with the scenario 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 build margin (BM), with an average participation of 50% and 50%, respectively. All coefficients are expressed in tCO2/MWh. The project boundary is the interconnected national system.

3.4 Estimating the Om Emission Factor

To calculate the operating margin (OM) emission factor, the following options are available:

(a) Simple OM,

(b) Simple adjusted OM,

(c) Dispatch data analysis OM, and

(d) Average OM.

The selected option to calculate OM for Los Azufres III project is the Simple OM, since the data needed in the computation are readily available. OM is calculated as the generation-weighted average CO2 emissions per net unit electricity generation (tCO2/MWh) of all generating power plants serving the system, but excluding the low-cost / must-run power plants / units.

For the first crediting period, calculations for OM emission factor will be done using the *ex-ante option*, because the Interconnected National Mexican System is highly complex. In fact, it is an aggregate of 177 power plants that use different sources of energy, such as heavy oil, natural gas, diesel, coal, nuclear, wind, geothermal, etc. Thus, it is tedious inconvenient to calculate the annual OM factor.

Based on the premises and as a primary estimation, we took the value of Simple OM ex – ante emission factor calculation from La Venta II project, which is the last CDM project registered by CFE (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:

$$EF_{OMsimple,y} = \frac{\sum_m EG_{i,j,y} * COEF_{i,j}}{\sum_j EG_{j,y}} \quad (1)$$

Where:

$EF_{OMsimple,y,}$	=	Simple operating margin CO2 emission factor in year y (tCO2/MWh)
$EG_{i,j,y}$	=	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*.
$EF_{CO2,m,i,y}$	=	Average CO_2 emission factor of fuel type *i* used in power unit *m* in year *y* (tCO_2/GJ)

Conversion efficiencies of power units were taken from the official internal reports of CFE. With this information the weighted average of net efficiencies conversion for every fuel was obtained. Table 1 shows the parameters extracted from the original PDD for OM calculation.

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
30%	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

3.5 Estimating the Build Margin Emission Factor (BM)

BM 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 are available and calculated as follows:

$$EF_{grid,BM,y} = \frac{\sum EG_{m,y} EF_{EL,m,y}}{\sum_m EG_{m,y}} \qquad (2)$$

Where:

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

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

$EF_{EL,m,y}$ = CO2 emission factor of power unit m in year *y* (tCO2/MWh)

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 years for which power generation data is available, or the later capacity additions to conform 20% of system generation. Must use the data with bigger annual generation;

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

Following the same concept similar to OM, estimation of BM emission factor will be done using the ex – ante option Calculations are also taken from the La Venta II project PDD, as shown in Table 2.

3.6. Combined Margin (CM) Emissions Factor

The CM coefficient is determined by applying the following expression:

$$CM = \left(EF_{OM,y} * W_{OM}\right) + \left(EF_{BM,y} * W_{BM}\right) \qquad (3)$$

Where:

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

$EF_{grid,BM,y}$ = Build 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, W_{OM}=0.5 and W_{BM}=0.5 for first crediting period. Thus, the CM coefficient can be obtained as follows:

$EF_{grid,CM,y}$ = (0.70036*0.5) + (0.41085 * 0.5)

= 0.5556 tCO2/MWh

Table 2. Build Margin ex-ante to LAGF.

	Tech. Part Tecnology	MWh 2005-2003	NEC (%)	tCO2e
0%	Coal	0	33.05	
95%	Natural Gas Combined Cycle	40,963,715	45.85	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	263,836
0%	Diesel	11,431	26.10	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

Table 3. Los Azufres III incremental capacity and non condensable gases

CONCEPT	North zone	South zone
Los Azufres net capacity, MW	50	25
Back pressure existing capacity, MW	20	15
Incremental capacity, MW	30	10
Incremental steam comsumption, ton/h	106	4
Total steam consumption, ton/h	380	210
Capacity factor	0.85	0.85
Gas content, %w	3	10
Gas composition:		
CO2, %w	97	97
H2S, %w	2	2
NH4, %w	1	1

Source: Data provided by CFE

3.7. Steps to Estimate CO2 Emissions Reduction Due to the Los Azufres Iii Activity

Since the project activity consists of installing and operating two (2) new units located in different zones of the geothermal field, where steam is produced with different physicochemical properties, estimations of emission reductions must be done separately for the north and south zones, as follows:

a) Baseline CO_2 emissions reduction from electricity delivered by the new project due to the incremental capacity, using CM coefficient.

b) CO_2 fugitive emissions derived from the new project incremental steam requirements.

c) Total emission reductions due to the new project operations is obtained by deducting fugitive emissions from baseline CO_2 emissions reduction, both calculated in (a) and (b) steps above.

3.8 Estimating Baseline CO2 Emissions Reduction

Baseline CO_2 emissions reduction from electricity delivered by the new project are estimated for each field zone using CM coefficient and the data shown in Table 3.

$$BEy = EGy * CM \tag{4}$$

Where:

BEy = Baseline emissions in year y (tCO2/yr)

EGy = Incremental electricity delivered by the project activity to the grid, (MWh/yr)

CM = Combined margin CO2 emission factor (tCO2/MWh)

North zone:

BEy = (30 MW/h) * (8760 h/yr) *(0.85)* (0.5556)

BEy = 124,110 tCO2/yr

South zone:

BEy = (10 MW/h) * (8760 h/yr) *(0.85)* (0.5556)

BEy = 41,370 tCO2/yr

From these values, we will discount the fugitive emissions that will be discharged to the atmosphere, resulting from the incremental 110 t/h of steam required.

3.9 Fugitive emissions from Los Azufres III project

For Los Azufres III geothermal project, fugitive emissions are associated with the non condensable gas (NCG) content in the steam. These gases are extracted from the condenser and discharged into the atmosphere through the cooling tower.

Fugitive emissions can be obtained by using the following equation:

$$PE_y = W_{CO2} * M_{S,y} \tag{5}$$

Where:

W_{CO2} = Average mass fraction of carbon dioxide in the produced steam (non-dimensional).

Ms,y = Quantity of steam consumed during the year *y* (tones).

Applying the data from Table 3, we can obtain the following results: $PEy_{\text{North zone}}$ = 27,021 tCO2/yr and $PEy_{\text{South zone}}$ = 3,399 tCO2/yr.

3.10 Final Estimation of Emissions Reduction (ER)

The final estimation of CO_2 emissions reduction will be obtained by subtracting the fugitive emissions from the baseline CO_2 emissions reduction, previously calculated. The results are as the follows:

North Zone:

ERy = = 124,110 tCO2/yr – 27,021 tCO2/yr

= 97,089 tCO2/yr

South zone:

ERy = 41,370 tCO2/yr – 3399 tCO2/yr

= 37,971 tCO2/yr

The total ER for Los Azufres III project increases to 135,060 tCO2/yr.

CONCLUSIONS

Los Azufres III project will avoid emissions estimated at 135,060 tCO2/yr, from which 97,089 tCO2/yr are the contribution of the North zone of the geothermal field. This means that 2.5 times of the ER t will be produced from the project in the South zone.

The South zone reservoir has a high non condensable gases content (10%), which, in the beginning could mean an unviable CDM project for its probable low contribution in terms of ER. However, by taking into account the CO_2 emissions already coming out from three existing power plants, the benefits can be obtained from the change in technology, specifically by changing the back pressure units to a condensing one, which represents an increase in conversion efficiency with a lower emission factor in kgCO2/kWh. The present steam rate is of 13.7 kg/kWh. Thus, the expected value for the North zone is of 8.4 kg/kWh and 7.6 kg/kWh for the South zone.

Los Azufres III could yield economic benefits from the sale of CERs in the international carbon market, ranging from €202,590 per year (the lowest price estimated in €1.5, referred from Carbon, 2009) to €1´755,780 per year (highest price estimated in €13, referred from Carbon, 2009).Using an average price of €7 would give an estimate of €945,420 per year. The capital cost for the Los Azufres III is expected to reach around €110 million. An emissions reduction purchase agreement for 10 years would represent €7 million in present value (6% of discount rate) which translates to 6.4% of the project capital cost.

In conclusion, this paper has shown that the Clean Development Mechanism (CDM) is a useful tool of the Kyoto Protocol in encouraging the development of geothermal energy projects, even in the case of the Los Azufres III, a geothermal resource with high gas content.

REFERENCES

ACM0002/Version 09: “Consolidated baseline methodology for grid-connected electricity generation from renewable sources”. CDM-Executive Board. UNFCCC/CCNUCC EB 45 (2007), 1-19.

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

Carbon (2009). “Carbon 2009 –Emission trading coming home”. Tvinnereim, E., Roine, K.Heimdal, C. pp. 11-13, 24-25.

EB 35/Annex 12/Version 01.1: “Tool to calculate the emission factor for an electricity system”. CDM-Executive Board. Pp.: 1-15.

Luege (2002) J.L., and Fernández A and Martínez J.: National Gas Inventory 1990-2002, Report of México, Executive Summary, Proceedings,Secretaria de Medio Ambiente y Recursos Naturales, Instituto Nacional de Ecologia, México (2005).

Stern (2007) Nicholas: The Economics of Climate Change. Executive summary, i – xi.

Torres (2007) M.A., Mendoza A., and Flores M.: Proyecto Azufres III 75 MW, DINYAC-021-2007, Subgerencia de estudios, Comisión Federal de Electricidad, 3-7, 14-29.

Comisión Federal de Electricidad, www.cfe.gob.mx

Secretaría de Energía, www.sener.gob.mx