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Environmental impact assessment for alternative-energy power plants in México

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Abstract: *Ten Environmental Impact Assessment Reports (EIAR) were reviewed for projects involving alternative power plants in Mexico developed during the last twelve years. Our analysis focused on the methods used to assess the impacts produced by hydroelectric and geothermal power projects. These methods used to assess impacts in EIARs ranged from the most simple, descriptive criteria, to quantitative models. These methods are not concordant with the level of the EIAR required by the environmental authority or even, with the kind of project developed. It is concluded that there is no correlation between the tools used to assess impacts and the assigned type of the EIAR. Because the methods to assess impacts produced by these power projects have not changed during 2000 years, we propose a quantitative method, based on ecological criteria and tools, to assess the impacts produced by hydroelectric and geothermal plants, according to the specific characteristics of the project. The proposed method is supported by environmental norms, and can assist environmental authorities in assigning the correct level and tools to be applied to hydroelectric and geothermal projects. The proposed method can be adapted to other production activities in Mexico and to other countries.*

Key words: *Hydroelectric, Geothermal, Environmental impact assessment.*

Introduction

Approximately 95% of the 100 million inhabitants of Mexico have access to electricity. According to official data, the residential sector will be fully electrified by the end of 2009 (SENER, 2002). Electricity consumption was originally projected to increase 3.5% annually from 2000 to 2030. However, reality has made such numbers obsolete. Consumption will increase from 16% of in 2000 to 21% in 2030 (SENER, 2002). Hydroelectric and geothermal power plants currently produce about 26.53% and 2.41% (3150 MW and 115 MW, respectively) of the total energy consumed in Mexico.

Mexico has more than 300 hydrological basins with annual runoff of 400 billion cubic meters, but distribution of this resource is not uniform. For this reason, the majority of hydroelectric projects have been developed in southwestern Mexico, which is lightly populated, so most of the power production is transmitted to the center and north of Mexico.

Hydroelectric potential is approximately 82,300 GWH. In contrast, geothermal potential is only 1,100 MW of capacity. Nationally, about 500 thermal geothermal sites of different kinds, hot water, fumaroles, volcanic mud, sofataras, wells, or a combination of these sources (SENER, 2002), have been identified.

Electricity from hydro and geothermal projects will increase nearly 2% annually for the next six years. Hydroelectric and geothermal projects represent more ecological friendly alternatives to the oil and gas burning of about 14.4% and 3.3% of the electricity generated in Mexico (Breceda, 2000).

However, both hydroelectric and geothermal power plants have environmental costs (Lawrence, 2001). These facilities can have a significant, but localized, impact on the environment during construction and operation phases (International Energy Agency, 1998). Hydropower can cause extinction or endangerment of freshwater fish species.

Large-scale hydropower project also have significant large, detrimental impacts on fragile ecosystems (Vaughan *et al.,* 2001). In Mexico an Environmental Impact Assessment Report (EIAR), is required by environmental authorities before a company or agency receives authorization to develop the project.

Mexican environmental law (SEMARNAT, 2002) requires that all electricity generation projects must develop an EIAR. The first step is to present a Prevent Report (PR), where all project activities that could affect the environment are described. After reviewing the PR, environmental authorities decide if the developers should present an EIAR, and if so, at which of three levels: General, Intermediate or Specific. The determination of level of EIAR required should depend on the magnitude and impacts of the project.

Presently, no objective criteria are available for environmental agencies to use to establish which level of an EIAR to assign to a given project, or to determine what methods should be required to assess the impact. In this work authors analyzed the most common techniques used to assess environmental impacts of hydroelectric and geothermic projects in Mexico. The findings may lead to recommendations for helping Mexican authorities to make appropriate decisions to protect the environment and to protect local communities from environmental degradation resulting from the projects.

Materials and Methods

To evaluate the techniques and methods used in

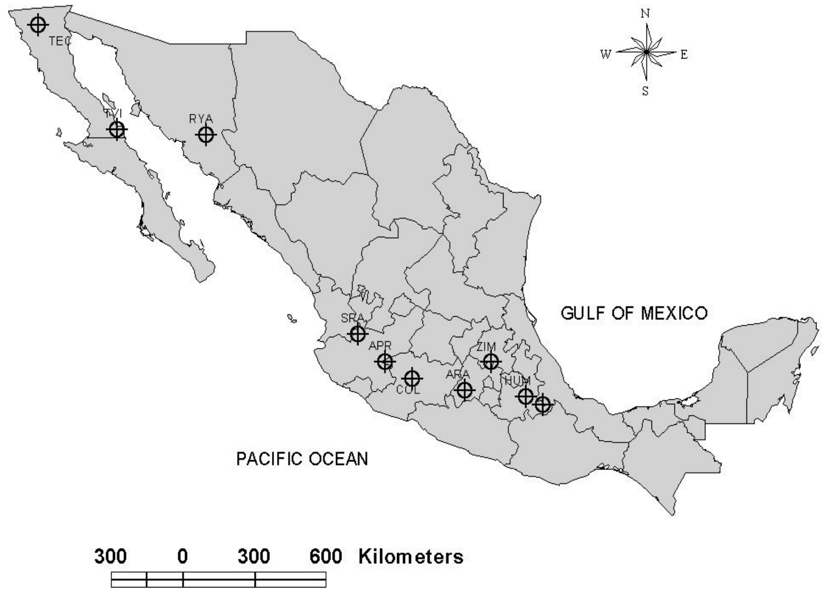

Fig.1: Map of location of hydroelectric and geothermic projects

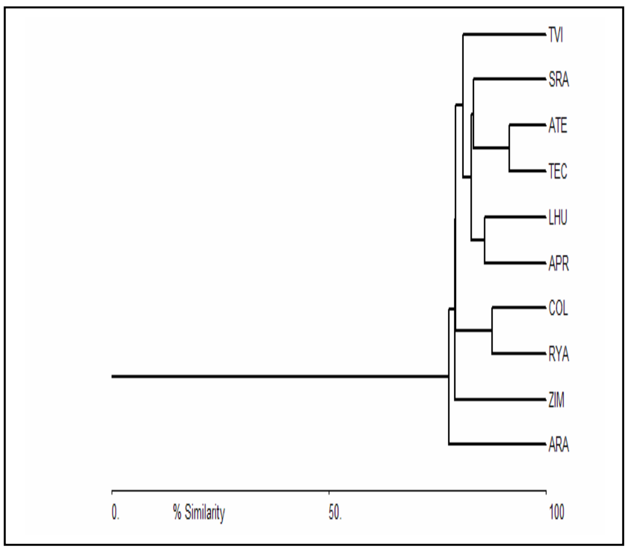

Fig. 2: Cluster analysis for the EIARs from 1988-2000 CPPs.

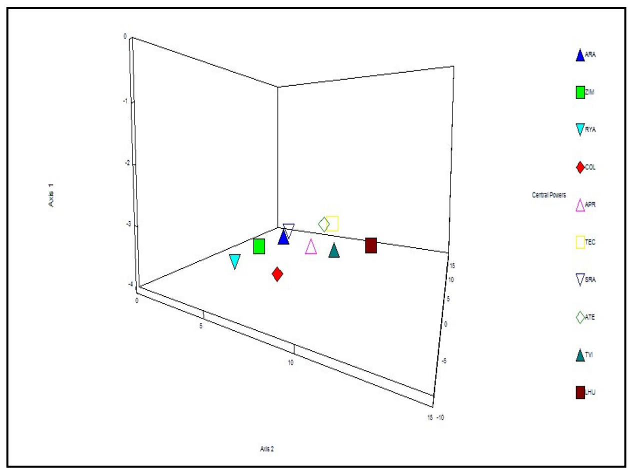

Fig. 3: Principal component analysis for the EIARs from 1988-2000 CPPs.

Mexico to determine the effects on the environment produced by construction and operation of Hydroelectric Power Plants (HPPs) and Geothermal Power Plants (GPPs), authors reviewed all the EIARs developed between 1988 and 2000.

The information analyzed included: name, location, influence area of the project, type of project, type of energy, energy production (MW), project area, type of report, number of methods used, population affected, type of consultant, and distance to natural protected areas (Fig. 1).

All information compiled was normalized, and to all analyzed parameters were assigned a quantitative value (Table 1, 2 and 3). Quantitative data were analyzed using biodiversity (McAleece, 1992, Version 2), and statistical (Version 5.), software programs to calculate cluster analysis and correspondence analysis, respectively. Cluster correspondence and principal components were studied to distinguish what were the common characteristics of the ten EIAR.

Results

The EIARs for HPP and GPPs presented to Mexican environmental authorities over a twelve year period (1988 to 2000); (Table 4). Three groups were distinguished by the cluster analysis (Fig. 2).

Group 1 corresponded to the ARA, a tiny geothermal project that produced around 1-50 MW.

Group 2 comprised ZIM, RYA and COL, projects that shared two characteristics: of using the Leopold or /and Sieved matrix method to evaluate the EIAR and the project did not

Table – 1: Main characteristics at thermoelectrical project plants (TPPs) in environmental impact assessment reports analyzed.

Scale	Location	Number of districts influence for HPPs and GPPs	Project kind	Project area (ha)	Fuel kind	Energy production (MW)
1	Northwest	1	Hydroelectric	.1-50	Water runoff	1-50
2	North-center	2	Geothermic	51-100	Water vapor	51-100
3	Northeast	3		101-150		101-150
4	Occident	4		151-200		151-200
5	Center	5		201-250		201-250
6	Metropolitan	6		251-300		251-300
7	Orient-center	7		301-350		301-350
8	Orient-golf	8		351-400		351-400
9	South	9		401-450		401-450
10	Southeast	10		451-500		451-500
11	Peninsula	11		>501		>501

Table – 2: Characteristics of hydroelectric and geothermal project plants (HPP and GPPs) in EIARs analyzed.

Scale	Report kind	Population kind	Consolatory kind	Population	50< distance to natural area (km)	50> distance to natural area (km)
1	General	1-2499 (Rural)	Educational institution	Yes	Yes	Yes
2	Intermediate	2,500-14,999 (semi-urban)	Private advisory	No	No	No
3	Specific	15,000 or more (urban)	Government Institution			
4	Risk analysis					
5	Environmental diagnostic					

affect natural areas.

Group 3 was divided in two subgroups. The first subgroup comprised the APR, TEC, SRA, and ATE projects, all hydroelectric projects that used water runoff, to produce from 1 to 50 MW. Excepting APR, the rest of the HPP projects were developed by a government institution.

Subgroup two included TVI and LHU, GPPs, that use water vapor and producing 1 to 50 MW and are more than 500 ha in area.

Fig. 3 shows the results of the principal components analysis performed for all analyzed HPPs and GPPs. As it is possible to observe in the three panels, there are few environmental, social, economic or even project characteristic that determine which level of EIARs is assigned to each HPP and GPPs.

Neither is there any correspondence among project magnitude, kind of project, and environmental and social considerations with the methods used to assess the impacts produced by the project activities.

Cluster analysis and principal components results indicate that the HPPs and GPPs some similar characteristics and some differences (besides the obvious one). At the same time our results indicate incoherence between the level of the EIAR assigned and methods applied to assess the impact produced by HPPs and GPPs.

Discussion

Our results showed that, independently of the kind of GPP and HPP project, and the environmental and social characteristics of the area affected, the assigned EIAR level was not correlated with the expected effects to be produced by the alternative-energy electrical project. For GPP and HPP projects, the socioeconomic impacts caused are in general positive, and the principal impact factors are changes in air quality and water quality, and increased water consumption (SEMARNAP, 2000).

By contrast, HEIARs projects, with large dams that modify the morphodynamic and hydrology characteristics of the flow of water, can have potentially sizeable negative impacts on the indigenous population and ecosystems. In particular, flooding an area to be used as a reservoir may require the involuntary resettlement of people, may impoverish or destroy land and aquatic ecosystems upstream and downstream of the dam, and may seriously degrade the quality of water

Table – 3: Different method used to assess the impact of the hydro electrical and geothermal project plants.

Scale	Methods used to assess the impacts
1	Description
2	Property criterion
3	Checklist
4	Red, diagrams and graphics systems
5	Matrix Leopold and/or Sieve
6	Reduce Leopold matrix´s
7	Binary matrix
8	Evaluation matrix
9	Evaluation impacts system
10	Cartographic and photographic system
11	Superimposed information lands (transparent)
12	Basic equation and index
13	Modification scene
14	Coneza-Fernandez-Vitola method
15	Method ASTM
16	Method Secanes
17	Simulation Stella method
18	Mathematical methods
19	Model pollution dispersion
20	Combination methods 1+19
21	Combination methods 2+10
22	Combination methods 3+5

(SEMARNAP, 2002). Changing the flow of water may also compromise the use of the water downstream, having a mayor effect on fragile ecosystems (COFACE, 2002).

Lastly, the build up of the sediments around the dam may result in downstream erosion, as well as in eutrophication (SEMARNAP, 2000). These changes are the most important because they affect the utility life of the dams. In addition, , an HPPs project constitutes a visual intrusion, and may alter local climate, affect recreation and tourist activities, impact public health by increasing the mosquito and pathogen population, and could be a potential public health risk should impoundment fail (International Energy Agency, 1998). In contrast to HPPs and GPPs are one of the cleanest forms of energy now available in commercial quantities and also have socioeconomic benefits. These kinds of projects are an environmentally-sound alternative energy source, with low atmospheric emissions, thus diminishing potential problems to greenhouse gas emissions and other atmospheric pollutions (Klimpt, 2002) It is true, however, that GPPs may result in concentration of some elements from the geothermal fluids, which often requires remedial actions for environmental protection (Hurtado, 1999).

Despite the different magnitude of potential impacts between HPPs and GPPs, there exists an evident contradiction between these potential impacts of alternative-energy projects and the kind of methods used for their impact assessment. Mexican environmental law published in the ecological journal (Gaceta Ecológica, in Spanish) established that General EIAR requires only a description of the expected impact (such as the Leopold and /or Sieved matrix) (SEDESOL, 1989).

Environmental law established for Intermediate and Specific EIARs specified that the report must include semiquantitative and quantitative methods to assess potential

Table – 4: Main characteristics at all hydroelectrically and geothermal projects (HPPs and GPPs) the EIARs analyzed

HPPs and GPPs projects	NCPP	LOC	NDI	KCPP	KFU	ENE	ARE	KEI	NME	KME	POP	CON	AHA	50<	50>
Araro	ARA	4	1	2	2	1	1	1	1	5	2	3	2	2	2
Zimapan	ZIM	7	4	1	1	5	6	2	1	5	2	2	2	2	2
Rio yaqui	RYA	1	5	1	1	2	11	3	1	5	1	2	2	2	2
Cerritos colorados	COL	4	8	2	2	2	11	3	2	5	2	3	2	2	2
Agua prieta	APR	4	2	1	1	5	11	5	2	21	2	3	2	2	2
Tecate	TEC	11	1	1	1	1	1	2	2	20	2	2	2	2	2
San rafael	SRA	4	4	1	1	1	1	1	1	14	1	3	2	2	2
Atexcaco	ATE	7	1	1	1	1	1	1	1	21	2	3	2	2	2
Tres virgenes	TVI	11	2	2	2	1	11	4	1	11	2	3	2	2	2
Los humeros	LHU	7	4	2	2	1	11	1	3	22	3	3	2	2	2

Table – 5: Methods proposed for the EIARs projects.

Level required	Impact techniques required
General EIAR	Personal description, checklist, flow diagrams (Odum *et al.,* 1972), Leopold and/or Sieve matrix (Leopold *et al.,* 1971), and mathematical matrices(Peterson *et al.,* 1974),
Intermediate EIAR	Leopold and /Sieve matrix, mathematical matrices, environmental, cartography diversity and abundance indexes, overlays and computer-aided EIA (McHarg, 1968,1969),
Specific EIAR	Battelle method (Battelle Institute, 1972; Dee, *et al.,* 1973; Warner and Preston, 1973) Coneza-Vitola (Coneza, 1995), Multiattribute methods (Moskowitz *et al.,* 1978), Environmental models (air, water, soil, etc) and mathematical models.

Table – 6: Criteria for proposed use to establish the EIAR level of HPPs.

C1= Population kind having to be resettled	C2= Capacity (MW)	C3= Area of the reservoir flood zone (ha)	C4= Area of flood zone vs. valuation index	C5= Capacity of the reservoir (millions m^3)	C6= Water quality (NOM-001-ECOL)
a) Rural (less 2500 habitants)=1	a) 1-500= 1	a) 1-33,999= 1	a) Area with no particular value from an agricultural, aesthetic or cultural heritage point of view =1	a) 1-33,999= 1	a) Less NOM= 1
b) Semi-urban (2500-14999 habitants) =2	b) 501-1000= 2	b) 34,000-66,999= 2	b) Protected ecosystems ,ecosystem with high biodiversity and tourist interest=2	b) 34,000-66,999= 2	b) Equal NOM= 2
c) Urban (15000 o more habitants) =3	c) > 1000= 3	c) > 66,999= 3	c) Natural reserves, cultural heritage sites or site particular importance to ethnic groups =3	c) > 66,999= 3	c) More NOM = 3

Table – 7: Criteria proposed use for establishes the EIAR level of GPPs.

C1=Population kind define to SEMARNAT (2000)	C2=Local employment (% total of population around the project)	C3=Capacity (MW)	C4=Air quality (NOM-085-ECOL)	C5=Water quality (NOM-001-ECOL).	C6=Probability of a hazard (%)
a) Rural (less 2500 habitants)=1	a)1-33= 1	a) 1-250 =1	a) Less NOM= 1	a) Less NOM= 1	a) 1-33 = 1
b) Urban (15000 o more habitants) =3	b) 34-66= 2	b) 251-500=2	b) Equal NOM= 2	b) Equal NOM= 2	b) 34- 66= 2
c) Semi-urban (2500-14999 habitants) =2c	c) 67-100= 3	c) > 500= 3	c) More NOM = 3	c) More NOM = 3	c) 67-100 = 3

Table – 8: Evaluation of hydroelectric and geothermal projects according with the criteria's proposed.

HPPs and GPPS projects	NCPP	C1	C2	C3	C4	C5	C6	Total	Keiar
ARARO (CFE, 1989)	ARA	2	1	1	1	2	1	1.33	General
ZIMAPAN (Coplain, 1991)	ZIM	3	3	1	2	1	3	2.16	Intermediate
RIO YAQUI (TRIBASA, 1996)	RYA	1	3	1	2	3	1	1.83	General
C. COLORADOS (CFE, 1997a)	COL	1	1	1	1	1	1	1.00	General
AGUA PRIETA (CFE, 1993)	APR	3	1	2	2	1	3	2.00	Intermediate
TECATE (EPA-MEXICO, 1999)	TEC	1	3	3	2	1	1	1.83	General
SAN RAFAEL (CFE, 1997b)	SRA	1	3	1	1	2	1	1.50	General
ATEXACO (CFE, 2001)	ATE	1	3	1	2	1	3	1.83	General
TRES VIRGENES (CFE, 1998)	TVI	2	1	1	1	2	1	1.33	General
LOS HUMEROS (CFE, 1992)	LHU	1	1	1	2	1	1	1.16	General

impacts. However, according to our results, the reality is that the IEIAR and SEIAR we analyzed used mainly Leopold/Sieved matrix, description methods, dispersion models and superposition methodologies. While GEIARs used Checklist, Leopold and /or Sieved matrix, property criteria and Coneza-Vitola methods. Moreover, the level of EIAR for the both types of energy projects could be GEAIR, IEIAR, or SEAIR and environmental authorities do not consider the different characteristics of GPP and HPP projects to evaluate these projects. For this reason it would be very important if the Mexican environmental authorities could assign, based on objective criteria, the level of EIAR for alternative-energy projects.

We propose some methods to evaluate the EIAR projects according their level (Table 5). Also we propose the following procedure to assign such levels according to our results.

1. The developer must provide to environmental authorities the quantitative information regarding the six criteria listed in Tables 6 and 7 as the key factors in analyzing these kind of projects (C1 to C6). The environmental authorities must have open access to the raw data to be able to verify the quantification of the six criteria chosen.

2. Based on the quantitative data provided, the environmental authorities analyzing the project would then apply the following equation to determine the EIARs level to be assigned:

$$KEIAR = \sum (C1 + C2 + C3 + C4 + C5 + C6) / TC$$

Where: KEIAR= Kind of environmental impact assessment report; Cx = criteria's values proposed in Table 6 and 7, (x=1, 2,3,……n) and C= total number of the criteria's considered.

The quantitative result of the equation directly allows assigning the KEIAR according to the following scale: a) If the value is less than 1.0, the projects only need the preliminary Inform, b) if the value is between 1.1 and 1.9, this project requires a general EIAR, c) if the value between 2.0 and 2.9, the project requires an intermediate EIAR and d) if the value is equal or more than 3, the project requires a specific EIARs. Mexican environmental authorities should be able to demand a proper technique for each level of impact report required. Table 6 and 7 describe our proposal of the mandatory methods for each KEIAR. For these strategic reasons we propose an objective scale to assign a proper level for any HPPs and GPPs, and we propose the assessment techniques required using for each selected level. The Table 8 shows the evaluation of the HPP and GPP projects according to the criteria proposed by us.

The purpose of and HEIAR and GEIAR should not be to generate paper-work, but foster informed decisions and to determine the optional mitigation measures. All these can only be accomplished if the level of the EIAR is properly assigned, and if the methods used to assess the impact are appropriate for each case. Only in this way can the Environmental Impact Assessment lead to an understanding of the environmental consequences produced by each project and become an effective tool to take proper actions.

Our proposed method to determinate the level of the HEIAR and GEIAR has many advantages over the current way in which environmental authorities assign the levels. Our method establishes quantitative criteria and quickly identifies some possible natural and social environmental impacts. Also, it enables, based on quantitative criteria, to determine which methodologies are mandatory for the impact assessment for each EIAR level. In this way the official evaluator has an objective and easy tool to determine which are the best levels of EAIRs for each specific project and suggest, immediately, the corresponding level needed. Also, EIARs usually end after the decision to proceed with the project has been made, as shown. Unfortunately the EIARs as currently developed in Mexico are often undertaken only to satisfy the bureaucratic requirements of the environmental authorities. Following our proposal the GEIARs and HEIARs will be a real factor to enhance the sustainable development of Mexico. Therefore, authors conclude that at present in Mexico, the environmental impact assessment is not a tool to promote the sustainable development (Bruhn-Tysk and Eklund, 2002) and, as it is applied, the mandated EIAR does not promote intragenerational and intergeneration equities.

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