Methodology for the Evaluation of Environmental Costs in Thermal Generation in Peru

Jessica Meza Zamata[a], Wilver Auccahuasi[b], Lucas Herrera[c], César Santos Mejia[d], Juan Grados[e], Ciro Teran Dianderas[f], Juan Mendoza Nolorbe[g], Edilberto Calcina Zamata[h], Santiago Rubiños[i], Karin Rojas[j], Christian Ovalle[k], Jorge Figueroa Revilla[l], Ana Barrera Loza[m] and Ruben Quispe Ichpas[n]

[a, d, e, f, g, h, i] Universidad Nacional Del Callao, Lima, Perú
[b] Universidad Privada del Norte, Lima, Perú
[c] Universidad Continental , Huancayo, Perú
[j] Universidad Tecnológica del Perú ,Lima, Perú
[k] Universidad Autónoma de Ica, Ica, Perú
[l] Universidad de San Martin de Porres, Lima, Perú
[m] Universidad Nacional José Faustino Sánchez Carrión, Lima, Perú
[n] Universidad César Vallejo, Lima, Perú

corresponding author: Wilver Auccahuasi, Universidad Privada del Norte, wilver.auccahuasi@upn.edu.pe

Abstract. Evaluating the costs of electricity generation is important to be able to estimate the variable costs, characterized by the maintenance costs of the generation, transmission and distribution systems. In this work we evaluate the plants that use Camisea natural gas, which is an alternative to the plants that use fossil fuels, not only in terms of costs, but also in terms of the levels of contamination that they cause. The method presented can be taken as a reference for other evaluation mechanisms with similar characteristics.

Keywords: Fuel, camisea, natural gas, pollution, electric power.

1. Introduction

The DL Nº 1002-2008, referring to the Investment for the Generation of Electricity, applying the use of clean energy, which refers of importance for the country, in order to improve the quality of life of the Peruvian population [1]. At present there are many projects mainly dedicated to evaluate electricity generation systems using solar panels and the use of air, which has a low level of pollution on the environment.

A literature search on the use of gases caused by the consumption of solid fuels shows that they are affecting the entire planetary ecosystem, one of the serious consequences is related to the loss of glacial cover, measured by the loss of polar ice [2]. One of the reasons why the research group is motivated to carry out the present project is to be able to demonstrate that the environmental costs caused by the use of fossil fuels can be evaluated.

2. Materials and methods

2.1. Regulations

Performing a search on the regulations that are in force in Peru. Regarding electric energy, in all its generation sources, we have Law Nº 28611 General Environmental Law; Law Nº 27446 Law of the National System of Environmental Impact Evaluation; Legislative Decree Nº 757 Framework Law for the Growth of Private Investment, Decree Law Nº 25844 Law of Electric Concessions.

In order to know the issues related to the generation of electricity and how to measure the environmental cost, we can indicate that several principles, such as those related to sustainable development, studies on the environmental consequences of the energy industry, we have the allowable limits of pollution, we consider the national inventory of infocarbon.

2.2. Externalities

We consider as externalities, those related to the costs and/or benefits of the productive activities of the energy sector [5]. The level of pollution is not evaluated in the projects related to the generation of electric energy; these are one of the important factors when evaluating externalities [6]. In new projects related to electricity generation through the use of clean technology, it is a factor that is considered important [7].

2.3. Method to evaluate environmental costs

The method allows a measurement through the measurement of externalities, considering environmental external costs [8]. We can also consider in the process of analyzing other externalities, such as public health and environmental effects [9]. The method we propose is being considered in 5 stages according to the following detail shown in table 1.

In Figure 1, we describe in detail the 5 phases of the method, where the analysis mechanism is involved as well as how to calculate it.

Table 1. Description of the phases of the method

Phase	Name	Description
1	**Power description**	Consider: technology, energy used, capacity, among others.
2	**Calculation of generated energy**	Calculated by: energy = Hrs, of operation x Capacity where: Energy= energy produced measured ne MWh/y
3	**GHG calculation**	GHG calculation, depending on the type of fuel, where we Consider, E gei = type of energy X emission factor where: Energy type: estimated by GHG CO2 emissions per year, measured in Mwh per year. Emission factor in kg of CO2
4	**Emissions assessment**	Measures CO2 emissions by an economic value, calculated in tons and measured in soles.
5	**Cost calculation**	measured by the formula: Cost act = emission value per plant / energy produced in one year where:

		Cost act= cost measured in Soles/MWh Emission value per plant = economic value of emissions per plant measured in soles/year. Energy produced per year = energy produced in a year, measured by MWh/year.

3. Results

The results presented here are related to the application of the 5 phases, the evaluation of each of which is presented below:

Phase 1: Identification of the Thermal Power Plant

The district of Chilca is located in the department of Lima. There are 3 thermal power generation plants: Chilca 1 with 4 generators with a capacity of 851.80 MW, Kallpa with 3 generation units with a capacity of 979.00 MW and Fénix with 2 generators with a capacity of 575.00 MW.

Phase 2: Determination of Electricity Generation

table 2 shows the information related to electric power production:

Table 2. Energy produced

Name of the plant	Production in MWh in a year
Fénix	3913500
Chilca (1)	3403600
Kallpa	3974300

Phase 3: Determination of GHG Emissions

Once the telephone plant that uses fossil fuels has been identified, the GHG is estimated, as shown in Table 3.

Table 3. Emission factor by type of fuel

Fuel	Emission factor measured per Kg of CO2 in TJ
Natural gas	56 100
Carbon	94 600
Diesel	74 100

We then estimate the associated GHG emissions, as shown in Table 4.

Table 4. Emissions associated with the thermal plant

Thermal plant	Average energy production in TJ per year	Emission factor measured per Kg CO2 per TJ	Emission in tons of CO2 per year
Fénix	14 088.60	56 100	790 370. 46
Chilca (1)	12 252. 96	56 100	687 391. 06
Kallpa	14 307. 48	56 100	802 649. 06

Phase 4: Economic valuation of emissions

We calculated average carbon dioxide prices as well as carbon credits, evaluated according to the European stock exchange, at an exchange rate of the date, as shown in table 5.

Table 5. Historical prices of emissions

Date	Price over time measured in euros per tonne of CO2	Reference exchange rate	Price over time measured in soles per tonne of CO2
01/01/2019	8.34	4.088	34.08
01/02/2019	9.48	4.080	38.70
01/03/2019	11.54	4.060	46.86
01/04/2019	13.35	4.155	55.50
01/05/2019	14.78	3.978	58.78
01/06/2019	15.16	3.930	59.56
01/07/2019	16.35	3.950	64.52
01/08/2019	18.88	3.958	74.35
01/09/2019	21.43	3.940	84.63
01/10/2019	19.56	3.926	76.47
01/11/2019	19.22	3.977	76.83
01/12/2019	22.57	4.150	93.66
Average value	**15.89**	**4.016**	**63.66**

Figure 6 shows the economic value of CO2 emissions from the plants under investigation:

Table 6. Economic value of emissions

Name of the plant	Amount of emissions measured by tons of CO2 per year	Price over time measured in soles per ton of CO2	Value in soles per year
Fénix	790 370. 46	63. 66	50 315 597. 04
Chilca (1)	687 391. 06	63. 66	43 759 848. 24
Kallpa	802 649. 63	63. 66	51 097 298. 41

Phase 5: Environmental Cost Assessment

Figure 7 shows the data from the last phase, where the average environmental cost of CO2 emissions, measured by a unit value, is evaled.

Table 7. Environmental cost valuation

Name of the plant	Value in soles per year	Energy produced measured per MWh per year	Cost to the environment measured in soles per MWh per year
Fénix	50 315 597. 04	3 913 500. 00	12. 86
Chilca (1)	43 759 848. 24	3 403 600. 00	12. 86
Kallpa	51 097 298. 41	3 974 300. 00	12. 86

Table 8 shows the increase in the variable cost of the plants under investigation:

Table 8. Variable cost increase

Name of the plant	Variable cost measured in soles per MWh	Cost to the environment measured in soles MWh	Rate of increase in %
Fénix	13. 18	12. 86	97. 57 %
Chilca (1)	27. 95	12. 86	46. 01 %
Kallpa	29. 74	12. 86	43. 24 %

4. Conclusions

At the end of the research, we concluded that the costs related to gases emitted by the use of fossil fuels and is considered as greenhouse gases, are considered as externalities, in the evaluation model presented, is described objectively, making measurements of CO2 emissions, when the plants are in operation, the incorporation of these measurements considered as environmental costs, with the intention of raising awareness about the consequences of their emission into the environment.

5. References

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